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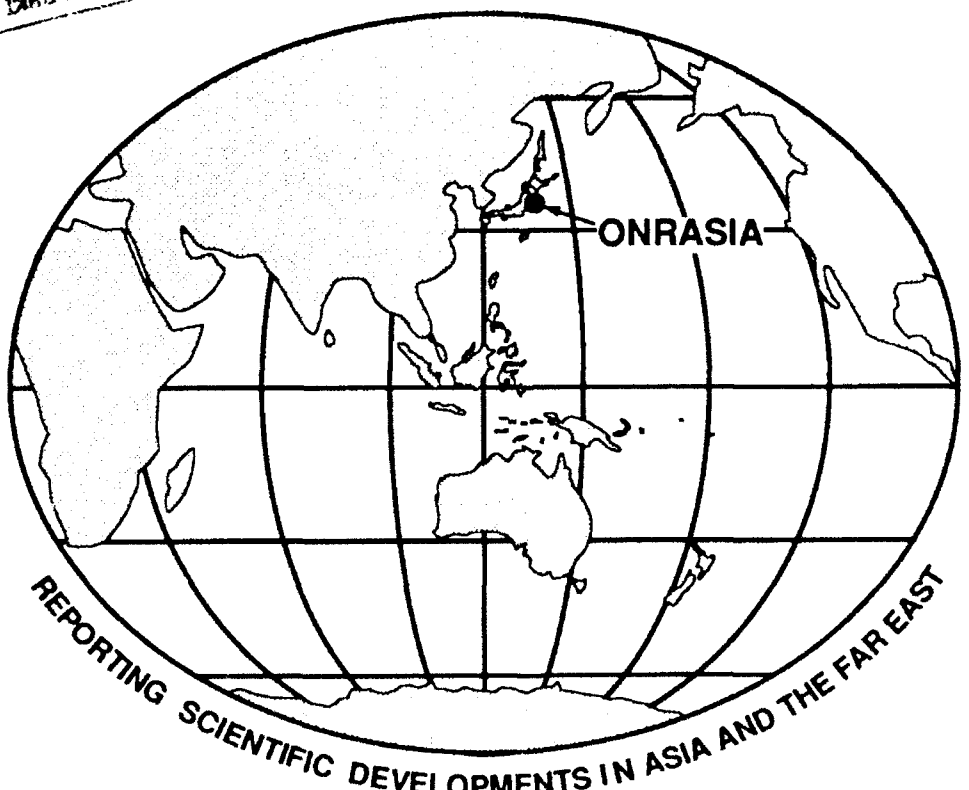

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This is a quarterly publication presenting articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONRASIA, with certain reports also being contributed by visiting stateside scientists. Occasionally, a regional scientist will be invited to submit an article covering his own work, considered to be of special interest. This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large. It is available free of charge to approved members of the DoD scientific community. Send written request describing DoD affiliation to: Director, Office of Naval Research, Asian Office, Unit 45002, APO AP 96337-0007.

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Manufacturing Science

Professor Yoshiharu Namba's research and development of a new technology is reported here. Professor Namba has designed a series of remarkably high-precision diamond turning and fine-particle slurry grinding processes. He combines his technology with United States made numerical controllers and measuring instruments to obtain further development of his research.

Material Science

The latest developments in the scientific research of zirconia-based ceramics and their transformations, mechanical properties, defect structure, and electrolytic behavior were presented at the Fifth International Conference on the Science and Technology of Zirconia. The electrolytic behavior of zirconia and its use in high temperature fuel cells and sensors are reviewed in this report. Research done in the United States, Japan, Europe, and in Australia/New Zeland is presented.

After three and one-half years from the announcement of spontaneous generation of "excess heat" during the electrolysis of deuterated lithium hydroxide dissolved in heavy water, significant progress in sorting out scientific fact from supposition or error has been reported during the Third International Conference on "cold fusion" held in Japan, October 22-25, 1992..

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SIBRIEFs

Scientific Information Briefs

SUPERCOMPUTER ITEMS FROM JAPAN, FUJITSU AND ICFD

FUJITSU'S NEW SUPERCOMPUTER

Fujitsu has announced the latest high-performance computer. This appears to be a cluster/crossbar system that uses a modest number of extremely powerful individual processors. Each processor includes a vector processor that has a peak performance of 1.6 GFLOPs and 256 MBytes memory. Processors use both BiCMOS LSI chips (72,000 gates and 200 ps delay time) as well as 45 GaAs LSI chips (25,000 gates and 60 ps delay time). One board contains vector and scalar units as well as memory for compactness.

Groups of 7 or 8 processors can be combined (the actual number depends on whether one counts the control processors), up to 222 units with a peak performance of over 355 GFLOPs. All processors are designed as LIW (Long Instruction Word) RISC units, with a synchronous operation of scalar, vector, and floating point units as well as communication. The system is networked by a crossbar, and communication units within each processor have a peak performance of 800 MBytes/s.

Fujitsu has named this series VPP500 and claimed that it can be purchased as a back-end to Fujitsu's current VP2000 line for current Fujitsu users. Users can compile on the VP2000 and use it as a file server to the VPP. Fujitsu will provide Unix System Vr4 as an operating system, and claims that software written for their VP systems can also be used on the VPP. The machine will use fully IEEE standard arithmetic (although the front end VP200 might stay with the IBM format). Delivery is expected in September 1993, and Fujitsu hopes to sell 50 systems within three years (20 in Japan and 30 to be exported). Fujitsu will OEM these to Siemens Nixdorf Information Systems, Germany. Rental prices are announced to be US$244,000—4.1M per month, with a purchase price of about US$125M for the largest system.

In an earlier report ["sacad.92", 1 July 1992,] I discussed several aspects of a Numerical Wind Tunnel (NWT) computer to be developed for the Japanese National Aerospace Laboratory, and that NAL was working with Fujitsu in the development of such a machine. This appears to be the new VPP. At the Fujitsu International Supercomputer Users Group Meeting, held in Paris, November 1992, a description of NAL's NWT showed that it will have the same compiler directives as the VPP. In February 1993, NAL hopes to get a system with 140 processors and is expecting 64 GFLOPs sustained for their real applications.

At the Paris meeting the ECMWF (European weather prediction community) discussed their needs. They are certainly interested in a VPP to replace their C90 system (undergoing acceptance tests) in about two years. Fujitsu would be happy to sell them one and is likely to concentrate on marketing outside of the United States. Of course, by then, other machines will appear in the market.

The development of the VPP follows a trend that we predicted in our assessment report on Japanese supercomputers [see "jhpc-sc.92", 28 June 1992].

(1) Focus on exploiting excellent device and packaging technology to push individual processor performance.

(2) A conservative trend with respect to very large numbers of processors, which are still viewed as difficult to program and use. The VPP system is really on a different track from Fujitsu's AP system; the latter can have up to 1K processors in a mesh architecture.

(3) Use of some GaAs in new generation machines, but conservatively.

INSTITUTE OF COMPUTATIONAL FLUID DYNAMICS (ICFD)

Dr. Kunio Kuwahara (sometimes Romanized as Kuwabara) has made headlines over the past few years. Using land in Haramachi that he owns (in

central Tokyo), Kuwahara built (next to his house) a center for supercomputer applications in fluid dynamics. He leased first one then another and eventually seven supercomputers (estimates are about US$80M) he used the land as collateral for bank loans. In addition to his own research, he leased out excess cycles, mostly to automobiie, steel, and chemical makers. Readers of my reports may remember that Dr. Hideo Yoshihara, who was in this office for two years until 1990, performed many benchmarks of Japanese supercomputers collaborating with scientists at ICFD.

Alas, a combination of hard economic times, falling land values, and direct supercomputer purchases by some of his customers eventually caused ICFD's money to run out. Now all six of the installed leased machines have been removed, leaving only a Thinking Machines CM-2, which was purchased outright. The official reason stated is that ICFD needed better management because of financial difficulties. Current plans are to give up the time-rental business and focus on consulting work by using parallel computers, such as Thinking Machines CM-2 and others. ICFD will also devote some of its business activities to selling workstation compatible software.

Kuwahara is still a flamboyant and colorful figure, once commenting that he didn't need any fancy software or techniques, just more cycles. He asserted that U.S. supercomputer makers such as Cray Research are *small* companies that build products largely by hand, and claimed that their machines were expensive and temperamental whereas Japanese companies with large product lines have excellent production technology, in-house semiconductor technology, and can spread development costs over an entire product line. -- *David K. Kahaner, ONRASIA*

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BACKGROUND ON MICROMACHINE ACTIVITIES IN JAPAN

In several previous reports, ["micromac.92", 22 Sept 1992, and "micro.mac", 11 Sept 1991] I described a new Japanese government project to perform research and development in the field of micromachines. Some background on the expectations and key problems are presented in this report. It is clear that the main applications will be first within the medical field. To develop the needed technology, however, computing, materials, electronic device manufacturing, and other areas of research will need to contribute.

MICROMACHINES

Intelligent micromachines for use in medical treatment and other fields are of increasing interest to the Japanese, and research for the purpose of producing micromachines continues to flourish in Japan. A close connection exists between the so-called intelligent materials and micromachines, in the sense that intelligent materials can become the materials for producing micromachines and their smaller versions, which should be called nanomachines.

In the world of micromachines the basic parts have dimensions that range from 10 nm to 1 mm. Obviously, applications of micromachines are in medical treatment, postassembly precision machinery, and in cases where precise work must be done in special kinds of environments such as high pressures and vacuums, such as the ocean or in space. But, at least in Japan, the use of micromachines in medical treatment is thought to be the most concrete application area.

Japanese reports show concrete images of potential micromachines used in medical treatment. For example a drug transport vehicle. Conventionally, the entire body gets a drug dose, whether it is given orally or by injection. This can limit the use of strong, potentially toxic drugs. One approach is research on drug delivery systems (DDS) that deliver drugs in appropriate ways, in order to focus the effects of the drugs in specific places and only for specific lengths of time. Another example relates to micro-robots. It ought to be possible to go through tubular cavities such as blood vessels, and the spinal cord cavity with a micro mobile robot. Then surgeons could insert a tiny laser endoscope into the diseased part and then a small manipulator attached to the end of the endoscope could cut out only as little as necessary of the diseased part of the body. If successful, this will have a major impact on surgical techniques. Of course, if advances are made in micromachine technology, there will also be dramatic progress in miniaturization, flexibility, and functions of artificial organs.

The problems that arise in micromachine design technology, as a result of size, are the marked increase in frictional resistance, viscous resistance,

surface resistance, and the noticeable decrease in strength. In these areas, the feeling in Japan is that we must understand our bodies in different ways than we did in the past. In the actual design phase, rigorous computer simulation is felt to be essential. In this regard, I have not seen any significant research related to computer modeling of micromachines in Japan.

For "micromachining," the technology for producing micromachines, in addition to applying the fine processing technology used to produce semiconductors, methods that involve using protein engineering and atomic manipulation to assemble molecules and atoms together will also be needed.

One recent example of micromachine production technology is the trial manufacture of cantilever-beam-type actuators that mimic the ciliary movement of living organisms. Each of these actuators consists of a cantilever made from two kinds of polyamides that have different rates of thermal expansion, and a metallic resistance wire sandwiched between two polyamide sheets. In their initial state, the cantilevers curve up about 250 μ from the substrate because of the residual stress. When current flows through the resistance wire, Joule heating heats up the cantilevers and, like a bimetal, they bend down to the substrate. By distributing many of these actuators over the surface of a material, the material surface can be endowed with transport functions, and a tiny carrier machine can be realized.

Research on bacterial flagella to find a model for micromachines in living organisms is energetically being carried out, here. Flagella use protein molecules as parts, and they are referred to as nature's smallest *molecular motors*; to a bacteria, they play the role of a screw. Recently, it was reported that experiments to freely control the rotational speed of flagella were successful [Nihon Keizai Shimbun, 20 May 1991, p. 19]. This was built upon the discovery that the rotational speed of the flagella of Salmonella bacteria, which were fixed in a nutrient medium on the tip of a glass tube 1 μm in diameter, was proportional to the voltage that was applied between two electrodes set up on the inside and outside of the tube.

In view of the importance of micromachine production technology, Japan's New Energy Development Organization (NEDO) began a "Micromachine Technology" as a new project. It began in 1991, as part of a large MITI-AIST project (the Large Industrial Technology R&D System). This is a ten-year R&D project of about 25B Yen funded by MITI. As I have reported previously, many Japanese companies are participating, and in Japan, significant progress is anticipated in the field. While this report focuses on Japanese activities, I should point out that there is a great deal of similar work in progress in the West. In fact, I recently saw an excellent demonstration of experiments that were conducted at IBM's Japan Technical Research Laboratory clearly indicating that Big Blue is extremely interested in the topic. -- *David K. Kahaner, ONRASIA*

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REMARKS ON VIRTUAL REALITY ACTIVITIES IN JAPAN

I have written several reports on Virtual Reality (VR), Artificial Reality, and Tele-existence. ["icat.92", 5 Aug 1992, "vr.991", 9 Oct 1991.] In these reports I mentioned that most of the hardware used has been imported from the United States, and that the first large scale commercial applications are thought to be for games.

The current report is a combination of (mostly) newspaper and trade journal articles. Much of the text is puffy and has an obvious "spin". As far as I can tell, it describes technology that will already be well known to the VR research community. Nevertheless, I have combined and distributed it here to emphasize the following points.

(1) Japanese researchers are developing VR hardware of their own, as well as developing interesting applications outside the game arena.

(2) Japanese companies are becoming seriously interested in this technology and seem intent on making use of it as a problem solving tool.

(3) Japanese companies see the VR market potentially lucrative for hardware that will be developed in Japan, unilaterally and as joint projects with U.S. companies.

(4) Japanese companies realize that the ability to operate devices intuitively by ordinary gesture-like motions can be exploited in many practical fields. The Japanese also realize that present man-machine interfaces could be made easier, even if these interfaces fall short of outright VR.

1. APPLICATIONS

- — CAD Systems (NEC)
- — Gesture recognition (ATR Labs)
- — Software analysis and development (Tokyo Electric Power)
- — Construction Robots (Tokyu Construction, Musashi Inst of Technology, Fujita Construction)
- — Power Plant Monitoring (Hitachi)
- — Molecular Modelling

2. FORCE FEEDBACK EXPERIMENTS

Iwata (Tsukuba)
Sato (Tokyo Institute of Technology)

3. BUSINESS RELATED

Nissho Electronics, Ltd. (Japan) agreement with VPL (United States) Media Int. Corp. (MICO) (Japan) agreement with Telepresence Res (U.S.) Japan Tech Transfer Assoc (JTTAS) sets us AR and Tele-Exis Res Committee

APPLICATIONS

Virtual Reality applications to CAD Systems, Construction Robots, Software. From: Tokyo Nikkei Mechanical, Apr 92 pp 56-66.

Researchers are making progress on the use of VR in equipment operation. Unlike the devices that perform 2-D movements like mice or joy-sticks, VR seeks to employ ordinary human motions and spatial movements in the operation of equipment. Nippon Electric Co., Ltd. (NEC) is doing research on using VR in a 3-D CAD system, and at the same time Tokyo Electric Power Co., Ltd. is working on a system in which VR is used to analyze software. Tokyu Construction Co., Ltd. is seeking to adopt a VR-based system for the remote-control operation of construction robots. Fujita is doing research jointly with the U.S. company VPL on a VR application in operating construction robots via communications lines.

VR technology uses computer graphics and 3-D images, so as to make what does not actually exist then and there appear to the operator as though it does exist, and the operator can use hand or finger movements to move an object around, or alter its shape, in virtual space. Progress is being made in research that aims to such objects inside virtual space in place of 3-D CAD shape models or actual construction robots. A robot, of course, moves in three dimensional, and 3-D CAD obviously uses 3-D space. VR enables all kinds of operations to be done via human movement. A "hand" or "arm" inside "space" is linked to the 3-D movements of the machine or model being manipulated, thereby facilitating intuitive comprehension of what is happening. Researchers hope to make this technology useful in handling 3-D CAD and manipulating construction robots.

For example, in a CAD system input, we are talking about entering a flat drawing, then a mouse is perfectly adequate. It is a different story, however, if we try to enter a 3-D object. You can move a mouse around easily on a flat surface, but you cannot move it around freely in a 3-D space. A mouse simply cannot give the operator a true sense that he or she is working with a 3-D representation.

Research efforts are now being directed toward the use of VR in incorporating 3-D movements and developing input interfaces that allow intuitive operation.

Transforming 3-D CAD Models With 'Data-Gloves'

NEC's C&C System Research Laboratory has developed a VR system in which a 3-D CAD shape model can be manipulated with a feeling of actually touching it with the hands. With this system, it is easy to perform operations in which it appears that a model is being manipulated as though it were made of clay. The shape of the model can be changed, it can be sculpted, and parts can be added or deleted by using "one's own hands (*agents*) appearing on the screen." The movement of these *agents* is linked to those of data-gloves which the operator actually wears. This gives the feeling of actually handling the model directly with one's hands. This feeling cannot be realized by manipulating a mouse.

The input device used in the NEC system are data-gloves made by the U.S. company VPL. This is a glove-shaped device that permits hand-position and finger-bend data to be input through the use of magnetic sensors and optical fiber. Also used is a system made by the U.S. company Solidary Laboratory with liquid-crystal shutter glasses to produce a 3-D solid image. The 3-D image is produced by changing from the left-eye to the right-eye images with the liquid-crystal shutters.

The model, the hands that manipulate the model, and the operator's hand agents appear on the screen. Every operator wears data-gloves on both hands, so two hand agents are described on the screen for each operator. The model is gripped, is moved about, and its attitude is changed with the agents. When two terminals are linked together and joint manipulations are performed, four agents appear on the screen. There are triangular and rectangular icons at the top of the screen for calling functions to shift the perspective or change the color.

The general shape of the model is changed by using a planar cursor. When the shapes of the hands wearing the data-gloves are altered, the agents are transformed from hand shape to panel shape. This panel is the planar cursor, can be moved to any position or attitude by moving the hands. The model is cut or sculpted in this plane at suitable locations and thereby shaped.

The planar cursor represents positions in 3-D space and also the inclination of the plane in that space, so it is very difficult to manipulate the planar cursor with a mouse that can only move in two dimensions. With the data-gloves, however, one need only tilt one's hands to put the model in the attitude in which it needs to be cut. The advantage is that manipulations can be made intuitively without learning any special procedures.

When a yellow plate is touched by an agent, the *toolbox* is called up. The toolbox contains prefabricated shape models and parts. A shape model can be pulled out with the agent and compared with the model being designed, or a part can be added.

For instance, if you want to add tires to the model body of a car, 3-D computer graphics alone are not adequate for getting the right positions," says Shoji Kawagoe, a research section chief in the Terminal System Research Department of NEC's C&C System Research Laboratory. "You need something that gives you a 3-D view." Here again, we are talking about incorporating a sense of intuitiveness into the work; a process similar to what you have when building a plastic model.

It is also possible to change the agents to a pointer shape by altering one's hand gestures. This pointer is used to designate a specific part of a model that is being studied by more than one person. A coloring function called a *color ring* can be called up by touching the green plate. The model is placed in the middle of the color ring, and the model is colored by designating the desired color in the ring by means of the pointer.

Need High-Positional Precision in Input Unit for Serious CAD Work

"We developed this system for the use of 3-D CAD in a network environment," explains Kawagoe. The idea is to connect remote sites via communications lines in a system wherein a number of people can simultaneously study the same CAD model. The peculiar sense of immediate *presence* afforded by VR is employed to make it seem like the model is actually there where the operator is when he or she is manipulating it. "We plan to move our development work in the direction of further enhancing CAD functions," said Kawagoe.

For serious use, however, the data-gloves do not provide adequate precision. They can detect positions in 3-D space by use of magnetic sensors. The precision of this detection is only to within several centimeters, and it is readily influenced by metal objects located in the vicinity. It is therefore very time-consuming to adjust the system. The data-glove is a simple device in which optical fibers and sensors are installed in a glove. That is why it is now used so widely in research on VR application systems. According to Kawagoe, for future practical applications, "the poor precision afforded by 'data-gloves' is a system bottleneck relative to CAD needs." What is needed is a new spatial positioning input device.

Recognizing Gestures with Image Processing

Even though various manipulations can be performed merely by moving one's hands, it is nevertheless troublesome to use a special device like data-gloves that must be worn. It would be much better if VR environments could be used without this annoyance. Researchers at ATR Communication System Research Institute (Kyoto) are working on a system that uses image processing to recognize facial expressions and gestures. Such a system would provide a more natural interface that could be used without wearing any kind of special gear.

The ATR system employs images captured by two overhead CCD cameras. An image of the hand is abstracted, and the positions of the center of gravity and of the tips of the fingers are determined. In this way the shape and position of the hands are discovered. It is possible to tell whether the fingers are bent or not by the distance from the center of gravity to the finger tips. The positional precision

depends on the broadness of the space in which the positions must be detected. If the hands are to be moved within a cubic area 1 m on a side, then a precision of about 5 cm; i.e., several percent of one side, can be achieved. "Currently the positional precision is about the same as with the data-gloves," says Haruo Takemura, a researcher working in the Knowledge Processing Laboratory at ATR Communications System Research Institute.

Recognition based on multiple signs are built up by combinations of finger-number and finger-bending patterns. It is difficult to distinguish between individual fingers, however. The system can tell a thumb from a forefinger, but not a forefinger from a middle finger. When a SUN 3/260 system is used as the host, four recognitions can be made every second. Recently, the system has been improved to speed up this recognition speed, and a speed of 15 recognitions per second has been achieved.

This sign recognition is all based on static signs at the current time, but Takemura speaks of a "desire to move development efforts toward recognizing gestures" from continuously changing *dynamic* sign patterns. If continuous changes can be recognized, ATR researchers believe that it will be possible to distinguish individual fingers.

ATR is also doing active research on line-of-sight detection and on detecting facial characteristics. The goal is to combine these techniques so that an object can be manipulated in virtual space by image processing alone, without the operator having to don special gear.

3-D Imaging of Software Structures for Analysis Design

VR input is also being studied in applications that involve computer program design. The Systems Research Laboratory under Tokyo Electric Power Company's Technology Development Headquarters is doing research on a system in which intertask relationships during program execution are represented as 3-D images. The intertask relationships are studied as one manipulates the 3-D images with the hands while wearing data-gloves. The features in this system are divided between *visual analysis* and *visual design*. The visual-analysis features are used to extract bugs and analyze task structures. The visual-design features are used to convert the results of modifying the program to source code. The intuitive manipulation made possible by VR plays a major role in the system.

In visual analysis, trace data is first extracted from a program that is running and rendered visible as a solid 3-D image. The trace data consists of data on the internal operating conditions when a program is running, that is, when a particular task started and when it stopped, what files or tasks were called up, and so on. The image is displayed on a large back-projection display and made 3-D visible with liquid-shutter glasses. The tasks or files represented as rectangular parallelepipeds in 3-D space are gripped and moved with the hands while wearing data-gloves to analyze the program, extract bugs, and adjust the program. By appealing to the operator's intuition, this method lets one analyze or modify programs easily.

The operational status of the control programs used in Tokyo Power's central control facility is rendered three-dimensionally visible based on actual trace data. A thick white line in the middle of the display represents the time axis. Files and tasks are called up in the order in which they are connected by the other lines, thereby indicating how the program is operating. By watching this screen, it is easy to see the timing with which tasks are run and files are called up while the program is executing.

To modify a program one can use the data-gloves to move or add internal structures inside the program as it is being represented in 3-D. The company has provided the system with 13 different modes in which the data-gloves can pose. They are used to enlarge or reduce the image on the screen and to move the figure in the screen, in conjunction with commands for opening menus and making selections therefrom. These features are used in making modifications in a program. Tasks can be gripped with an agent, for example, and moved back and forth along the time line to alter the operational timing of those tasks. It is also possible to insert a completely new task. The system immediately performs a simulation to determine the effects of changing the task positions and update the screen display.

In the past, numerical trace-data outputs had to be read by somebody, and a line diagram (like a train routing diagram) had to be created before a control program could be studied. When studying the effect of altering the call-up timing, the lines had to be redrawn. A transformer-station control program contains more than 20 tasks and 20 files each, so a line diagram on paper was very complicated. It is difficult to look at such a diagram and understand it immediately, and redrawing the lines is tricky.

The system used by Tokyo Electric Power Co. (Tepco) at its System Research Laboratory not only automates such analysis work, but also three-dimensionalizes the analysis by means of VR technology and facilitates manual manipulation. These are very attractive features. By imparting a virtual shape to a program that is not a physical object, it is possible to employ human intuition with a sense that the object *itself* is being moved with the hands. It is hoped that this approach will make such analysis work more efficiently.

Mikio Okada, a lead researcher working in the laboratory's Control Research Lab said the following. "We will finish the interface portion this year. We then hope to get to the practical level within 2 more years." With the visual-analysis functions of the same system, complex relationships between tasks and files within a program can be represented in a form that humans can readily comprehend. This technology should have applications in process control systems, in production lines, as well as in software research.

Research has also moved ahead to the next stage, namely that of visual design. Visual design, according to Okada, is "a feature for expanding a picture in software." It is visual design that takes the 3-D figures or diagrams analyzed by visual analysis and converts them to source code. The goal is to achieve a system that takes the results of manipulated figures or diagrams and directly reflects these in programs.

In the past, research was conducted on the generation of program text code from symbols. This, however, was limited to lower command levels, even within a program structure. Evidently, little research has been done on taking the large program structures constituted by task relationships and transforming these from symbols to source code.

We have now reached the level where the call relationships between tasks, or between tasks and files, can be converted to code. Now, the next step is to do research on encoding chronological relationships and call-up timing. "It is very hard to properly reflect wait times," says one researcher working in the Control Research Laboratory.

When used in visual analysis, the precision of the data-gloves has little effect. When doing the visual design, however, this precision does become a problem because time relationships must be expressed exactly at positions in 3-D space. Researchers hope to be able to reflect time relationships in conjunction with the visual-design features by the end of next year.

VR Brings On-site Feel to Remote Control of Construction Robots

Research on input systems using VR technology is not limited to the field of CAD or other program software. It is also being conducted in hardware fields like robotics. Tokyu Construction is studying a VR system with the objective of using it in the remote control of deep-foundation work robots (a type of construction robot). Researchers are seeking to control construction robots with 3-D images and hand movements. This is a subfield within VR that is called tele-existence.

When the smallness of the diameter of an opening prevents the entry of construction equipment, human workers dig holes and put the foundations in place. These are called deep foundations. Robots have been developed to replace humans in this deep-foundation work. After the hole is dug out, the excavated surfaces are lined with steel plates called liner plates, and the foundation concrete is poured in. Accordingly, the diameter of the excavated hole must be made larger than the diameter of the foundation being put in place by the thickness of the liner plate.

In a remote-control situation, the positional relationship between the robot bucket and the excavated surface must be known accurately. Tokyu compared the work precision in three cases,

(1) when using images from one camera,
(2) when using 3-D visualization employing two cameras, and
(3) when relying on the naked eye.

It was found that the sense of positional relationships in space with 2-D screen images taken with one camera is inadequate, and that 3-D visualization is necessary. It was also demonstrated that the 3-D visualization of images taken with two cameras provide roughly the same degree of work precision as is provided by the naked eye.

With the remote-control system now being developed, a stereo visual image is taken by using two CCD cameras to achieve 3-D visualization. Two CRT screens equipped with polaroid filters are then synthesized with half-mirrors to achieve this 3-D realization. This permits a 3-D visualization system

to be configured more simply than when using a head-mounted display or the liquid-crystal shutter technique that switches the image between the two eyes at high speed. "We can obtain good pictures at low cost," says Masayuki Takasu, director of the Mechatronics Development Lab under Tokyu Construction's Technology Headquarters concerning the reason this method was adopted.

Electrohydraulic Bilateral Control gives *Feel* During Manipulation

A dedicated position input device is used to move a bucket when excavating. For this position input device, the arm of a small experiment-type shovel is shortened to one-fifth the normal size. To move the shovel bucket to the position aimed at performing excavation work, the operator moves the input device that he or she holds while watching a 3-D image. With the position input device and the small shovel, an electrohydraulic bilateral control system is configured, which has an electrical system on the input side and an hydraulic system on the output side. Research is being done on this project with the cooperation of Miroku Sato, a professor at Musashi Institute of Technology, who is working in the Control Engineering Research Laboratory, Mechanical Engineering Department, School of Engineering, Musashi Institute of Technology.

The valves of hydraulic actuators are controlled with the conventional lever-type control structures. However, no immediate relationship was apparent between the vertical and horizontal movements of the levers on the one hand, and the movements of the arm on the other hand, so, considerable skill was required to operate the arm and bucket correctly with the levers. With this new method, however, it is claimed that a beginner can excavate in the desired location. The lever operation requires considerable skill to accurately determine the excavation position. The new method, instead, can easily determine the position with great precision.

This system is equipped with load cells on both the input and output sides to give the operator *feel* when he or she is excavating and thereby appeal to the tactile sense. Very little research is being done on the use of VR to realize this sense of touch. "It's a big help on the job just to be able to feel some kind of feedback when a force acts on the tip of the bucket," explains Takasu. With *feel*, the operator can tell when he or she has struck a hard layer, so this sensory feedback is absolutely necessary for deep-foundation robot-operating systems.

The difficulty in using force feedback is said to be the adjustment of the load cells. The full force acting on the bucket cannot be returned to the operator; such force would be too strong. After a proportional reduction is made, however, some appropriate fraction of this force must be returned, "It is very difficult to find the best proportionality because of the differences between individual operators," says Takasu. "The fatigue factor will be too great if the force returned is too large. But there will not be enough *feel* if the force returned is too weak." Now that researchers see their way clear to realizing some degree of positional precision, they are working on ways to determine the optimal operating-force feedback proportion while increasing the number of samples.

Long Communications Line Linked to Construction Site

The construction company Fujita is conducting joint research with VPL (which developed the data-glove system) on applications of VR technology for construction robots. Again, the basic goal is to develop remote-control systems. More specifically, however, the two companies want to be able to connect domestic or overseas construction sites via ISDN (Integrated Service Digital Network) lines to control construction robots from a control center and to monitor and control site conditions.

Fujita is primarily responsible for developing the hardware for the construction robots and communications technology, while VPL is responsible for developing the software for the computer graphics and VR technology used with the construction robots.

In the system that is now being tested experimentally, camera images and computer graphics are synthesized and viewed on a 3-D display that the operator wears. The video images give the operator a sense of being right there at the construction site, and he or she can manipulate the robot easily with cursors or pointers displayed with computer graphics. The overall system is divided between Japan (Fujita) and the United States (VPL) so that researchers can experiment with remote-control operations over extremely long distances. "We have created a situation in which a construction robot in America can be controlled from Japan," says Kenichi

Kawamura, a vice president with Fujita Research (subsidiary of the Japanese parent company) who is in charge of the project.

"The biggest task problem facing us now is the time delay involved in long-distance communications," says Kawamura. This is not much of a problem when both the construction site and the control center are in Japan. When one is in Japan and the other in the United States, however, there is a delay of a second or more from the time the command is given until the robot actually moves. The same is true when sending a camera image from the robot. The company hopes to cope with the delay problem by using computer simulations of the robot movements and displaying predicted motions on the operator screen.

Other needs include technology for sending 3-D video data at high speeds and input devices that have high-positional precision. Fujita hopes to solve these problems before the end of 1992. "We hope to use this technology to create monitoring and control systems to reduce manpower requirements at construction sites and facilitate better remote management and control," says Kawamura in reference to future goals.

Exploiting Sense of *Being There* Provided by Camera Images

There are other possibilities for creating easy-to-understand interfaces besides VR. It is also possible to impart a sense of *being there* and thereby enhance operability by means of real camera images. The Hitachi Research Institute of Hitachi Ltd. has developed a prototype of a plant monitoring system that uses camera images to provide such a sense of *being there*. This system does not use 3-D visualization or other VR technology, but does give a real sense of plant work-site conditions and thereby seeks to enhance operability.

The prototype system is a model of a monitoring system for a thermal power plant. The condition of the plant can be monitored and controlled by directly manipulating the camera images. These direct manipulations of the camera images are conducted in the following way. Suppose, for example, that there is a need to check on the condition of the fire under a boiler; the operator uses a mouse to move a pointer and clicks it over the image of a boiler peephole. A frame will then appear on the screen, which indicates that a peephole has been selected as the device. When the peephole is clicked again, the screen will switch to an expanded image of the peephole. When the mouse is clicked a third time, the screen will change to the image of the flames that a monitoring camera is taking. The object that one wishes to view can be seen merely by indicating it on the screen, thus making operation extremely simple.

When changing the operational status, the operating panel image can be called up by using the mouse to designate the image of the device. Once the image of the control panel appears, the dials thereof can be designated with the mouse, and these dials can be tuned by moving the mouse. The dials on the control panel at the work site will move as the mouse is moved, and hence the operational status of the equipment will be changed. It is also possible to listen to the sounds being made at the work site and make decisions on the status of the system based on these sounds.

FORCE FEEDBACK EXPERIMENTS

Iwata (Tsukuba University)
From: Tokyo TRIGGER May 92 pp 20-25.

"Until recently, most interaction research has been focused on the visual and auditory senses," explains Nadao Iwata, a lecturer in the Structural Engineering Department at Tsukuba University. "Research on the senses of touch and pressure have lagged behind. To enhance human manipulational sensation, however, we need to study the physical interactions that involve immediate bodily sensations as well as indirect sensations." If we run into a wall, we bounce off it. How far can we go in reproducing these sensations of touch and force, which are so common in our everyday experience in the realm of VR?

According to Iwata, there are four ways in which dynamic feedback can be currently expressed in VR technology.

a. Master-Manipulator Technique

By using a manipulator based on mechatronics technology, a physical reaction is communicated back to the operator as he or she performs actions in virtual space. This kind of equipment usually involves large-scale hardware and is very expensive. Hence it is thought to be unsuitable for human interfaces.

b. Wire (Tension) Utilization

By using this method, positions are detected from the length of wires and while those wire lengths are being controlled, and physical reactions are produced. Small movements, such as those made with the tips of the fingers, can be used to good effect. However, the range of movement is limited because the wires that stretch in all directions will become tangled.

c. Joy Stick

This is an input/output system made up of a control stick that can be freely tilted longitudinally and laterally, and equipment that detects the angle, direction, and force of the tilts. The advantage is desk-top compactness. The disadvantage is that the number of degrees of freedom is limited.

d. Data-Gloves

Progress in research is being made on feedback from gloves, in which shape-memorizing alloys and air-pressure cylinders are used. This technique is limited to what can be felt with the hands, however, and cannot express the sensation of running into and bouncing off a wall.

Each of the four approaches summarized above has its own advantages and shortcomings, and no system seems to have been found to be definitive. For the foreseeable future, therefore, it seems that these methods will be used either individually or in combinations to suit the application.

One of Iwata's experiments involves a feedback system that is being developed, which is based on the master manipulator approach. One immediately thinks of mammoth system at the mention of a robot arm, but the apparatus under development at the Iwata laboratory is a very compact desk-top system.

The system consists of a manipulator unit that follows hand or arm movements with 6° of freedom and three actuators that follow finger movements. The operator can move his or her hands and fingers independently. When the position and movement of the hand is detected by the sensors, a virtual hand in a monitor screen moves accordingly.

When the hand in the screen strikes an object, the manipulator motor is mechanically controlled so that the movement of the operator's hand is restricted to produce a real sense of resistance. Similarly, when a virtual rubber ball is grasped, one senses elasticity in one's hand, and when an object is lifted, the operator senses the weight of the object.

For the visual sense, instead of using an HMD (head-mounted display), this laboratory says it will project images just as they are on a high-resolution screen. This would result in having the operator's hands fixed to the manipulator coming into the field of vision, so a mirror is placed in front of the operator's face at an angle of 45° and the computer screen is projected there. Thus the mirror hides the hands from view.

"If we can recreate the trial-and-error environment of a design process in a VR environment, the time and effort spent making a mock-up could be sharply reduced," explains Iwata. "In the case of automobile design, for example. The designer has to make small models out of clay. By giving form to an inspiration, not only must the work be seen, but the sensation of the hands is also very important. If this kind of intuitive expression could be input, it would be possible to let the computer handle the tedious work of the design process."

At the Iwata laboratory, experiments are being conducted in which a single-lens reflex camera created on a computer-graphics screen is handled with virtual hands to determine its weight balance and how it feels when operated.

This manipulator also has its limitations, however. The biggest limitation is its *particularity*. No matter how the apparatus is set up, dead angles where work cannot be done are always found. An example might be the inability to reach an object immediately below the manipulator. This will no doubt result in having to configure the system to suit the nature and purpose of each job.

Feel of Going Up and Down Stairs

Another large-scale VR is under development at Iwata's Tsukuba laboratory. This is the virtual perambulator. Iwata wanted to build an apparatus that would take the previously separated bodily sensations and handle them together.

With this apparatus, the walker has his or her upper body fixed in place and an HMD placed on his or her head. The position of the head is detected with image sensors. Ultrasonic wave generators are attached to the walker's toes, and the positions of the walker's feet are determined by measuring the time required for the ultrasonic waves to reach receiver units placed in three different locations.

These motion data are sent to a computer that generates a virtual space, and the view through the HMD changes in real time in response to the movements of the walker.

The perambulator is made so that the sense of reaction or resistance associated with climbing or descending stairs is produced by tension on wires attached to the feet. When ascending a step, the wire length is regulated so that the take-off foot feels the force of resistance. To represent the reaction force in the case of opening a virtual door, a manipulator with 6° of freedom was fabricated.

Once this system is perfected, designers of large structures, city developers, and public park constructors can perform simulations to find out ahead of time what it feels like to walk around in such facilities.

"The demand for view assessment is bound to continue to grow," says Iwata. "Computer graphics are already being used, but, with this apparatus, bodily movement is coordinated with visual images, so that a more lifelike model can be experienced. I think it might have useful applications in simulating living environments. A new house could be experienced while it is still in the design stage, for example."

Subtle Sensations of Craftman's Fingertips Reproducible

Yukio Fukui, a researcher with the Product Science Research Institute operated by the Agency of Industrial Science and Technology under the Ministry of International Trade and Industry (MITI), has developed a force feedback apparatus that uses an XY recorder. XY recorders—which record changes in coordinates relative to vertical and horizontal axes—have been used for some time to record vibrations or temperature fluctuations. Fukui decided to use these recorders in the field of VR. His research falls into the "joy stick" category.

The head unit in the XY recorder is equipped with four-directional strain gauges. When a head is moved by hooking a fingertip into a depression in the middle of a gauge, a cursor moves on a screen.

Immediately one tries to follow the object in the screen. The operating feeling is no different than that experienced with a conventional mouse. But, when the cursor tries to bite into the object, the XY recorder stops dead in its tracks.

"The force and direction of the fingers are measured with the strain gauge; information on the position of the cursor on the screen is fed back and into the XY recorder, and the finger movement is restricted as though someone said, 'That's as far as you go'", explained Fukui.

This apparatus has three advantages. One is that it can move freely, without any constraints of particularity, so long as movement is limited to the two XY dimensions. Another advantage is that force control and computation is simpler than with robot arms and wire tension because the positions are determined by two XY coordinates. The third advantage is that the recorders used are commercially available.

Where would it be helpful to follow subtle shapes in a virtual environment?

"Sometimes you have an object with a curved surface that is only slightly deformed in one place. The deformation might be undetectable to the eye, but readily discernible to the touch. When making a metal mold or die, a skilled craftsman might feel it with his or her fingers and detect subtle curves that he or she then corrects. This kind of trial-and-error operation can be reproduced in a VR environment."

In other words, it is said to be possible to use a computer to feel subtle tactile sensations that cannot be expressed in words or be discerned visually.

"We can think of many applications in the field of education and training," says Fukui. "Students of shodo (Japanese calligraphy) could use this method to trace out the subtle pen strokes of the master. Wouldn't that be great?" Maybe this portends a future in which educational or training software will be sold not just for the *visual* (video) and *verbal* (audio) information it imparts, but also for the *feeling* of the master with which it enables the user to experience. Fukui says that he will start development work on other 3-D feedback devices. "We are now developing a system with which a stick that moves longitudinally, laterally, and vertically is operated to move something like a virtual spatula to trace out or transform shapes."

Iwata's comment on how the history of the human race could be likened to a series of attempts to broaden the *virtual world* (imaginative world) and thereby expand human awareness, made a lasting impression on me.

"Take the ordinary telephone," says Iwata, "You truly experience this expansion of the virtual when you listen to the voice of someone speaking on the other side of the planet. The same can be said of sitting in your parlor and watching things happening on the surface of the moon. In like manner, VR has

the potential for explosively expanding our world of awareness."

It is amazing to see the world of data, inside a computer, spread tangibly before your eyes by VR, and thrilling to experience the initial moment of entering the imaginary world that is created. VR technology continues to make all kinds of *impacts* on us.

And now, the sensory information that is fed back to us in real time from the world of VR presents new world vistas to us. We can visit the interiors of virtual buildings, or we can delve into the world of molecules, and experience the feeling of taking action and doing work. And in the course of this process we gain intuitive understanding of a kind that heretofore had been inaccessible.

"What is the sense of reality to a human being?" As we work out the answer to this question, we may be incorporating not only the tactile senses into the world of VR, but the senses of smell and taste as well.

Technology will continue to expand the world of our experience and awareness, without limit, until it seems that another world, a new earth, has fallen into our hands.

Sato (Tokyo Institute of Technology)

Makoto Sato, a professor at the Precision Engineering Research Laboratory of the Tokyo Institute of Technology, is the developer of SPIDAR (Space Interface Device for Artificial Reality.) This acronym is also suggestive of a *spider*.

One first sticks one's index finger into thimble-like rings. Each ring is suspended from all directions by wires. If you yank down on the ring, the length of the wires changes. These changes are measured with a rotary encoder to detect the position of the finger.

For the visual input, anaglyph-based stereoscopic vision is used. When red and green glasses are looked into, the operator sees a 3-D wire-frame jar in a large screen.

When I tried pushing the virtual jar with my finger while it was still in the thimble-like ring, the cylindrical jar caved in and took on the form of a large squarish peanut or gourd. My finger, meanwhile, was locked into place and could not be moved. It really felt as though I had bumped into something.

"When the finger reaches the position occupied by the object, the wire is restrained and your motion is restricted," explained Sato. "This reproduces the sensation of touching something."

Next I tried pushing on the bulges in the jar with my finger. The bulges gradually caved in, and the jar returned smoothly to its cylindrical shape. The jar has a constant volume, so pushing in on one place will bring the depressions back out. It feels like making a clay jar on a potter's wheel.

This unique apparatus developed from a very simple wish. Sato explains.

"Seven years ago I saw the Fujitsu pavilion's 3-D video at the science expo. I was extremely impressed. In one scene a DNA (deoxyribonucleic acid) double helix twists its way up toward the ceiling. It was so real; I wanted to reach out and touch it."

Sato thought how great it would be if only one could *touch* a virtual object. If one could only use his hands to move and change the shape of a physical object. Sato's idea became a reality just three years later, in 1988, at the science expo. He unveiled what might be called the predecessor of SPIDAR.

In this prototype apparatus, a ball is suspended from all directions by wires. When this ball is struck with the tip of a billiard stick, the motion of the ball is detected from changes in the length of the wires. These data are input into a computer, the virtual ball rolls and strikes another ball. The result might be called a *virtual billiard table*.

The dream of *touching* an imaginary object in VR was realized with this *virtual billiard table*. The next problem is that of controlling the reaction feedback from the object touched. It took four more years to create SPIDAR. With SPIDAR II, currently under development, both the index finger and thumb are used.

Sato calls his SPIDAR II the *world of virtual building blocks*." The system has two rings in which the fingers are inserted. Each ring is suspended from four wires, making eight wires in all. When the operator looks through 3-D glasses equipped with liquid-crystal shutters, he or she sees a stack of building blocks with holes in them and a stick passing through their centers.

"Try picking up a block with the thumb and index finger and moving it to another stick," said Sato. At first one can't judge the distance well and waves in thin air. The blocks were hard to grasp.

When one does grasp a block, the operator can immediately *feel* the object from the restraint on the wires. I had a difficult time transferring the block to another stick, and was relieved when I finally got the hole in the block on the stick and let the block drop.

"SPIDAR is most suitable for work calling for supple movements with the fingertips," Sato explained further. "In the future, we might develop applications of this technology in the field of tele-existence if we can perfect robot nurses or other robots which perform delicate operations."

"As to the future, we want to increase the number of fingers used, make it possible to employ both hands; make the work performed more complicated, and thus heighten the sense of reality. We also hope to develop 3-D input devices that are as compact and easy to use as a mouse."

Artists and illustrators have recently begun to make extensive use of computer graphics as tools for expressing their creations. Sato spoke enthusiastically about the need to develop a *3-D mouse* that could be used easily not only by specialists working in VR and robotics, but also by everyone who uses computer graphics.

VR Used in Molecular Design

The range of applications for such technology is very broad, extending past the CAD (computer aided design) field to education, medicine, and the amusement industry. "It is also useful in molecular design in such fields as pharmaceuticals and protein synthesis," said Iwata.

"Suppose, for instance, that you wish to make a new molecule by means of molecular bonding. You have to study the attraction and the potential that exists between molecules and find out where the low-potential, readily bondable locations are. In the world of giant molecules that have complex structures, however, the researcher is faced with myriads of parameters and conditions that exceed the processing limitations of computers. So, what do you do? You build a molecular model with computer graphics and then use virtual hands to manipulate and join the molecules."

(At the University of North Carolina, progress is already being made in applying VR technology to molecular and atomic structures. This is one example of a job in which efficiency is improved by juxtaposing the human sense of touch with VR technology.)

3. BUSINESS RELATED

Nissho Electronics, Ltd., has had an agreement with VPL since 1987 to act as the sole sales agent for the latter in Japan. VPL is a pioneer in the VR field in the United States. A press conference was held on March 5, 1992 at which the two companies announced a tie-up to conduct international business in this field. At the press conference, Atsushi Kato, manager of the Electronic Equipment Business Department at Nissho Electronics, called VR technology a *futuristic technology that will support Japan in the 21st century*, while J. Gilmore, president of VPL, said that the purpose of the tie-up was *internationalization based on a new stage, new staff, and world strategy*.

Since entering into the dealership agreement in 1987, Nissho Electronics has been marketing VPL's VR systems and VR-related products including data-gloves, eyephones, and the RB2 system to some 100 Japanese users (companies).

The two main elements in the business tie-up are the beginning of Japanese production and the formation of the *VR Club*.

Nissho Electronics has pursued the VR business as an import agent. This historical development has highlighted the necessity of implementing domestic production. What is most important in practical implementation of VR is not the hardware (the product itself) so much as the *soft* issues of how the user can use the hardware and how the user wants to use the hardware. Each individual user tends to look at a VR system or product and say something like this: "We at ABC Ltd. want to use your product for such and such particular purpose; can't we change or enhance this or that feature to better facilitate that purpose?" The *VR Club* was formed in response to this diversified demand. The idea is to make it possible for member companies to use basic VPL patents to produce their own products in Japan.

Nozomi Kikuchi, assistant manager of the Application Electronics Department at Nissho Electronics put it this way. "Companies apply for membership in the *VR Club* through Nissho Electronics. Final versions of the membership agreement and fee structure have yet to be hammered out, but we're working on it. Member companies can use the roughly 20 basic VR-related patents possessed by VPL to develop and produce their own applications. Progressing to manufacturing in Japan should break

the barrier to the full-fledged development of VR." Kikuchi said also that it would be fun to see how far products like the eyephone and data-glove would evolve with Japanese technology.

"It was magnetic sensors that got us involved in VR," says Kikuchi. "We were surveying the U.S. market seeking sales routes for our magnetic sensors when we found one company that wanted to buy in large quantities. We figured there must be some kind of really good application behind the big orders, so we went to visit the company. That company, of course, was VPL.

"At that time, nobody had ever heard of VR. Our first impression was that VPL was doing research in an area bordering on the fantastic. That's what I thought at first. And then we discovered that the VPL people were into something really amazing. So we thought, OK., let's try our hand at this and see what happens. That was back in 1986. Now VR has suddenly become a very hot topic. I guess we were just lucky."

The market has changed a lot in the past y ar, however, according to Kikuchi. Most of the .les prior to the change had been to laboratories and public organizations, primarily for research use. Now most of the inquiries have to do with product development. "We get a lot of inquiries from people who say they would like to work with us on this or that application," said Kikuchi. "We may now be entering an era when the curtain goes up on VR as a serious business."

VPL thinks the market potential may be in the neighborhood of 1 Trillion Yen, but the company is cautious, realizing the market is still being developed and that the new technology has not yet been put on a full commercial base. VR is attracting wide attention, and sales are definitely growing with a multiplier effect. "But the current status is just a step above outright R&D," says Kato.

The market that is being targeted is the engineering market in such fields as robotics. The objective is to improve productivity by using VR to simulate processes, time, and manufacturing steps.

"Fundamentally, though VR is a technology that can be used just about everywhere," says Kato. "In a sense, the applications are only limited by the user's imagination. So the differences in the types of jobs actually envisioned might not be such a problem."

MICO: Mass-Media Revolution?

Media International Corporation (MICO) has concluded a tie-up agreement with Telepresence Research. The latter was founded by Tom Fumace, a pioneer in VR in the United States, who did research at NASA's Ames Laboratory.

MICO, a trading company that deals in imaging and video software, was established by NHK, with the financial backing of C. Itoh & Co., Ltd., The Seiyu, Ltd., Dai-Ichi Kangyo Bank, Ltd., and Sumitomo Bank, Ltd. VR to MICO, is "a new communications media," says Akira Mochizuki, manager of MICO's Media Development Department.

MICO is working with affiliates of Telepresence Research (including Fake Space Laboratory, Nymark and Company, and Crystal River) to commercially develop such technologies as tele-robotics, local base entertainment systems, and both 3-D video and audio in virtual space.

"MICO is only interested in media products," explains Mochizuki, "so we see VR is a new media that is worth being pioneered."

What is interesting about MICO's VR business is that it focuses on software instead of hardware. "At the mention of VR, most people think of such 'hardware' as the HMD or data-gloves that people have to wear," continues Mochizuki. "But this isn't the way it is. VR, in the fundamental sense, is software and is media. It is software, therefore software should come first in our thinking about VR, not hardware. To be more specific, we shouldn't be concerned so much about whether the video quality is good or bad, but rather about how to use it; that is the key. It's like, in the beginning there was software. We should be successful if we make good software that capitalizes on the features of VR to transcend distance and time, and to be able to get inside our computers."

This will never happen, however, just by acting as a conduit for imports from America.

"MICO is not simply a trading company. We propose how to use VR, explore joint research projects, and think of software with users. We must handle everything here: coordination with American VR manufacturers, direction, and production."

The key to all of this is none other than domestic production. The 3-D display system "BOOM" currently being handled sells for around 10M Yen. By producing the system in Japan, this price can be cut by a third or even by half, it is believed.

With NHK heavily involved in MICO, there is naturally interest in connecting VR with communications and broadcasting, but Mochizuki quickly points out that such possibilities are still very much in the future.

"VR may provide the impetus for touching off a revolution in the shape of mass media. VR is not just for sending information like television does. It permits interactive, two-way communication. But we are still talking about raw potential here. Applications in communications and broadcasting are still quite a ways off."

Information Collection Complete; On To Business Targets

Since its formation by the JTTAS last October, the Artificial Reality and Tele-Existence Research Committee has already signed up some 90 participating companies. "As a research society, we're already vying for number one or two," laughs Shinji Ishikawa, a project leader.

Most of the early companies to join were in the electronics, mechatronics, and game manufacturing industries. Thanks perhaps to the current boom, however, the society is being joined by more and more advertising agencies, software production companies, computer graphics production companies, and other media related companies.

While this popularity of the research society is a most welcomed development, too many members can prove disruptive of the society's activities, so the structure of the society has been reorganized around subcommittees.

There are currently four subcommittees. The Simulation, Design, and Amusement Subcommittee, the Human Factor Subcommittee, the Robot Control and Communications Subcommittee, and the Internationalization Subcommittee.

"All of the member companies have evidently completed their information collection activities regarding VR," reports Ishikawa. "Now they are at the stage of figuring out what to do next, based on the information in hand. We are starting to see actual action. At this stage, however, we are not *Yet* seeing any products realized.

"In making VR a viable business, a decision must be made whether to regard it as a brand new technology or to handle it as a technology to be applied in the context of existing technologies. We are not yet seeing much in the way of products, but I think that maybe we could possibly see something like that in another 2 years or so."

What sort of businesses will have developed out of VR 2 years from now? Who knows. But you can be sure that, behind the scenes, each company is working feverishly in identifying and define a specific target. -- *David K. Kahaner, ONRASIA*

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INTERNATIONAL JOINT CONFERENCE ON NEURAL NETWORKS, NOVEMBER 3-6, 1992, BEIJING, CHINA PRC

This summary was prepared by

Lonce Wyse
Cognitive and Neural Systems Department
Boston University
111 Cummington St. #240
Boston, MA 02215
Email: LWYSE@PARK.BU.EDU

The International Joint Conference on Neural Networks was held in Beijing China, November 3-6. Financial support for the conference was furnished by the International Neural Network Society (INNS), the Institute for Electronic and Electrical Engineers (IEEE) Neural Network Council (NNC), the China Neural Network Council (CNNC), the IEEE Beijing Section, and the China National Natural Science Foundation. Much of the organizational work was done under the auspices of the Chinese Institute of Electronics (CIE) and was orchestrated by Dr. Yi Xin Zhong of the University of Posts and Telecommunication, Beijing 100088, P.R.C. Tel: 201-338 ext. 2203, Fax: 500-5233.

The opening plenary talk was delivered by Dr. Wu Youshou of the Tsing Hua University, Beijing 100084, P.R.C., the general Cochair for the conference and president of the CNNC, who gave some background information about neural network research in China. The CNNC is only two years old. There are 14 member societies that comprise the council and include the societies of Artificial Intelligence, Automation, Biophysics, Mathematics, Power

Engineers, Biology, and Psychology. The CNNC has organized several national neural network conferences, and the IJCNN'92 is the first such international conference. Another international conference on neural networks is being planned by the CNNC for 1994.

About a dozen books have been published in Chinese on the topic of neural networks, and Dr. Wu estimated that some 200 graduate students and postdoctorates are focusing their research on neural networks. From my discussions with representatives of the various universities around the country, I believe the number to be considerably higher than that if one includes those who are incorporating NNs as an essential part of an application. Dr. Ming Yihe (E.E. Dept., Northwestern Polytechnical University, Xi'an 710072 P.R.C.), for example, tells of about 30 such researchers who work at the NN laboratories that he founded at National Polytechnical University.

Dr. Yang XiHua of the Department of Electronic Engineering, Jiao Tong University, Shanghai 200052, P.R.C., invited me to give a talk after the conference at their university, which was attended by about 30 people. I was given a tour of the Image Processing and Pattern Recognition Laboratory where I saw demonstrations of video teleconferencing work (compression software and dedicated hardware), and a Hopfield network-derived image reconstruction technique. Most of the computer work is PC-based, but several workstations were also being used. I heard repeatedly, both here and from people at other universities, that a central hindrance to producing cutting-edge work is the lack of access to current international journals and books. Most journals appear on the library shelves six months to a year after their original publication date.

The IJCNN'92 proceedings include 563 papers, posters, and abstracts, about half of which are from outside the P.R.C. The conference was attended by almost 400 people, a little over 100 of whom were from outside the P.R.C. Japan was represented by about 30 people, the United States by approximately 20. The International Student Society for Neural Networks (P.O. Box 15661, Boston, MA 02215, U.S.A.), supported by the IEEE and INNS, was able to sponsor the attendance of five students from Korea, Turkey, Canada, Italy, and the United States.

Harold Szu (conference Program Chair and President-elect of INNS), Paul Werbos (National Science Foundation and President of INNS), Russ Eberhart (conference Cochair and President of the IEEE Neural Network Council) and Shun-ichi Amari (conference Cochair and Professor at Tokyo University) were all on hand and gave plenary session talks in which they expressed their pleasure with the development of research in the field, in China, and a belief in the impact that Chinese researchers will have in the coming years. -- *Lonce Wyse, Boston University*

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RESEARCH INSTITUTE OF MATHEMATICS (RIMS) WORKSHOPS, KYOTO JAPAN, 1992

Following the fine Japanese tradition of organizational precision, the Workshop on Numerical Methods at Kyoto University, Research Institute of Mathematics Science, Nov 4-6, 1992, began precisely at 13:30. The program consisted of seven 40-60 min invited talks given by senior researchers, and thirteen 30-min talks given by their younger colleagues. Unfortunately (or fortunately) submitted abstracts were subjected to refereeing since only a limited number of spaces were available. There was only one minor program change: Igarashi's talk was interchanged with that of Tado and Ono on the final afternoon. Since a formal write-up of the talks will be published as part of the Kyoto University RIMS Kokyuu Roku Series next year, I will try to comment only on those aspects of the presentations that may not appear in the proceedings.

This reporter would like to apologize in advance for any errors and mistranslations, that are due to her poor Japanese and mathematical background rather than intentional malice. Dr. Shaoliang Zhang (formerly with the Institute of Computational Fluid Dynamics) kindly corrected a misspelling of his name from last year's report. I think his Chinese name was pronounced by using the Japanese-way of reading Chinese characters and was then phonetically translated into English. Unfortunately, he tells me that most of his recent mail uses my "new" version of his name. I regret the error and appreciate his understanding and forgiveness.

Iri started the talks with a nice, informal talk that set the tone for the remainder of the meeting. The 60-min essay discussed his thoughts and advice on the interplay between numerical analysis and other disciplines. Some of his words of advice included:

(1) the importance of developing a well-rounded scientific and mathematical background to practice good numerical analysis. An understanding of the scientific modelling process is needed before numerical techniques can be applied, e.g., Vornoi Diagrams and computational geometry rely heavily on topology; Gershgorin's Theorem is used extensively in numerical analysis; statistics and related mathematical theory are needed in statistical computing.

(2) the need for caution when using automatic programs for graphing. The scaling must be the same on all graphs before comparisons are made; automatic tools often set scales according to the maximum or minimum of a particular graph. Excessive labelling, cluttered charts, and busy diagrams are sometimes produced when using the default options.

(3) the importance of increasing exchange, cooperation, and understanding between Japanese and overseas scientists. There is a perception that Japanese currently "take" more technology and ideas than they "give". If this perception is not changed as Japan becomes a greater economic and technological power, greater friction will undoubtedly arise. Professor Iri's talk was inspirational as well as educational and distinguished professors from other disciplines, including Kawai of Mathematical Physics attended. -- *Mei Kobayashi, Kyoto University*

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PACIFIC OCEAN REMOTE SENSING CONFERENCE 1992

The Pacific Ocean Remote Sensing Conference 1992 (PORSEC '92) was held during 25-31 August 1992 at the Okinawa Convention Center in Ginowan, Okinawa, which is approximately 30 min north of Naha by bus. The aims of the Conference were "to develop and apply remote sensing techniques by using not only satellites but also underwater acoustics, optics, buoys, etc., to ocean sciences and to investigate environmental phenomena concerned with meteorological or physical, chemical, and biological oceanography in the Pacific Ocean." This was the first of the PORSEC conferences to be held; the second is scheduled to be held in Melbourne, Australia, in March 1994. A strong international flavor seemed to dominate this meeting of approximately 210 participants, of which about 100 were non-Japanese. Nearly 200 papers were presented orally in four concurrent sessions and were divided into the following categories:

High frequency ocean radar
Thermal infrared
Underwater acoustics
Ocean color
Ocean surface processes
Applications to physical oceanography
Wind waves
Ocean currents
Microwave backscattering
Underwater optics
Aerosol corrections
Atmospheric radiation transfer
Ocean environment
Wind field and surface
Satellite altimetry
Polar oceanography
Primary production
Data processing
Water mass
Drifter, buoy systems
Ocean current and flux
Coastal management

Aside from the oral presentations, over 100 papers were scheduled for poster sessions; a vast majority from the former Soviet Union. In addition to the papers, three workshops were held and covered the topics of Ocean Color, Education and Training, and Satellite Altimetry for Oceanography.

The conference opened with a plenary session in which four overview lectures were presented. Professor Jiro Kondo, President of the Science Council of Japan, discussed the role of remote sensing in monitoring global environment; Dr. Robert Stewart, President of PORSEC, reminded us of the importance of in-situ "sea truth" monitoring; Professor Yoshiaki Toba of Tohoku University, President of the Oceanographic Society of Japan reviewed the characteristics of pure wind waves; and Professor Andre Morel of the University of Pierre and Marie Curie discussed the future use of satellite data in the ocean flux study.

A session was held in which the remote sensing programs of several nations were discussed. Tomio Asai, Ocean Research Institute, Tokyo University, discussed the Global Ocean Observation System (GOOS). He stated that today we do not know enough to put in place a full GOOS, which requires

effective national programs as well as well-coordinated international research programs. B. Gregory Mitchell of the National Aeronautics and Space Administration (NASA) presented his program and the proposed launch schedule of the future Earth Observation Satellites (EOS). A real problem they face is budget reductions. K. Tachi of Japan reviewed the satellites launched and scheduled to be launched by Japan. The physical oceanography program in Korea was discussed by B. Choi of Sung Kyun University. Most of what he presented, however, were at-sea studies. He Ming Xia, Ocean Remote Sensing and Ocean Optics Laboratory, Ocean University of Qingdao, presented the remote sensing program of China. Among their current projects are the study of the circulation and of the ocean flux on the continental shelf of the East China Sea.

Ocean color received considerable attention in terms of papers presented and with a one and a half day workshop. This writer attended the first part of the workshop during which several presentations were made. Nobuhiko Handa, water Research Institute, Nagoya University, presented his study of the chlorophyll distribution in the equatorial Pacific. He analyzed for chlorophyll a, b, and c by high performance liquid chromatography (HPLC); the results were lower than those expected from fluorimetry and he attributed this to the El Nino. Kazuo Iseki of the Seikai National Fisheries Research Institute, Nagasaki, discussed the marginal sea studies in Asia. In particular he presented the Marginal Sea Flux Experiment (MASFLEX) in the western Pacific. Satoru Taguchi of the Hokkaido National Fisheries Research Institute, presented results of the chlorophyll measurements he made on numerous cruises from northern Hokkaido to 39! N. Sin Jae Yoo of Korea discussed ocean color measurements in his country, which began in early 1991. The primary focus is on conductivity in the marginal seas: Yellow, East China and Japan Seas. Four Americans discussed on-going work in the United States. Raymond Smith of the University of California at Santa Barbara stressed the importance of simultaneous in-water measurements and pointed out the problems caused by clouds obstructing the view of the surface. James Yoder discussed his studies of a seven-year Coastal Zone Color Scanner (CZCS) in the middle Atlantic. B. Greg Mitchell of NASA discussed the problems of models—8 or 10 layers of models are needed to calculate primary production from ocean color data. Frank Muller-Karger of the University of South Florida reported that temperature is inverse to biomass as measured by pigment concentration.

This writer also attended the sessions on Coastal Management. Fumio Kaneko, Norio Katakura, and Tetsuo Yagura of Taisei Corporation, Narashino, Japan, presented the results of their study on seawater purification using a substratum of marine organisms. They used porous substratum (porous concrete) onto which macroorganisms, such as barnacles, hydrodies ezonensix and ulval pertusa, and microorganisms (diatoms) were recruited and used to treat seawater. They measured purification by observing removal of total organic carbon and gain in transmissivity. The role of remote sensing and its cost effectiveness in site selection for coastal aquaculture was discussed by R. Sudarshana of the Indian Institute of Remote Sensing, Dehradun, India and by M. S. Siddiqui of the Department of Zoology, Aligarh Muslim University, Aligarh, India. They used the Indian satellite, IRS-1A, which was launched in March 1988 with a Soviet launcher. The ecological factors they used were benthic biomass, phaeopigment, median diameter, humic substance, soil brightness, green vegetation index, and yellow substance index. Tadashi Inagaki, Ichiro Aoki, and Takeo Ishii of the Ocean Research Institute, Tokyo University, presented the results of their study on the acoustic estimation of plankton biomass. This study was made on a 130-day around-the-world cruise. The main objective of the study was to examine the relationship between net sample biomass and the acoustic volume scattering strength at four frequencies (200, 120, 50, and 38 Khz). From the equations obtained from a least squares fit between the biomass and the vertical distribution of the scattering, they were able to get a rough estimate of the biomass in the world's oceans. A. Hartoko and D. Suprato of the Coastal Region Eco-Development Laboratory, Diponegoro University, Indonesia, reported on their study of the application of remote sensing for coastal management in the north coast of Java. They used data from the Landsat satellite with which they mapped mangrove areas, brackish-water ponds, sea-water turbidity, and sea surface temperature.

The conference was active and there was a great deal of interaction among the participants. For further reports and information regarding the conference you may contact the meeting chairman

Professor Yasuhiro Sugimori
School of Marine Science and Technology

Tokai University
3020-1 Orido
Shimizu-shi, Shizuoka-ken 424
Japan
Tel: 81-543-34-0411
FAX- 81-543-35-4155 -- *Sachio Yamamoto, ONRASIA*

SEVENTEENTH INTERNATIONAL SYMPOSIUM ON MACROCYCLIC CHEMISTRY

The conference was held in Provo, Utah, USA, 9-14 August 1992. It focused on the latest progress made in theoretical and experimental aspects of the properties and behavior of synthetic and naturally occurring macrocyclic compounds.

Yohji Nakatsuji

INTRODUCTION

The Seventeenth International Symposium on Macrocyclic Chemistry (XVII ISMC) was held in Provo, Utah, U.S.A. on 9 through 14 August 1992. The symposium was partly sponsored by the international union of pure and applied chemistry (IUPAC). The previous five symposia had been held in Hiroshima, Japan (1987); Hamburg, Germany (1988); Townsville, Australia (1989); Odessa USSR (1990); and Sheffield, England (1991). Provo had about 240 participants representing 26 different nations. Out of these about half were from outside the United States of America. Japan had 12 representatives. There were one special award presentation, seven plenary lectures, 33 invited lectures, 15 short oral presentations, and 124 poster presentations. Some of the topics were:

1. analytical applications
2. binding with organic cations, anions, and neutral molecules
3. biological aspects
4. chemical sensors
5. industrial applications
6. kinetics and thermodynamics
7. molecular recognition
8. polymolecular compounds
9. structures of free and complex molecules
10. synthesis
11. biomimetic chemistry, and
12. selective chemical separations.

This report focuses on the lectures presented by the chemists from the United States of America and Japan.

BACKGROUND

Since the discovery of crown ethers by C. J. Pedersen (E. I. du Pont) in 1967, much effort has been devoted to the synthesis of crown compounds and the related analogues with an eye on their properties of selective complexation towards specific substances. D. J. Cram (University of California at Los Angeles), J. M. Lehn (University Louis Pasteur), and others have developed novel macrocyclic host compounds with attention to molecular detail, and have clarified the relationship between structure and complexation properties. These findings have been systematized as the concept of host-guest chemistry or supramolecular chemistry. The award of the Nobel Prize in chemistry to Pedersen, Cram, and Lehn, in 1987, was the highlight in the field of microcyclic chemistry. On the other hand, at the XIIth ISMC, held in Hiroshima, Japan; and chaired by: Professor Eiichi Kimura of Hiroshima University in 1987, the 20th anniversary of the discovery of crown ether was timely celebrated by awarding the Nobel Prize to the three persons mentioned above. This is regarded as evidence of the level of research in this field, in Japan.

A number of investigators in the United States of America other than Pedersen and Cram, have supported the remarkable development of

macrocyclic chemistry through this series of international symposia on macrocyclic chemistry. R. M. Izatt and J. J. Christensen, Brigham Young University, were the coorganizers of the first symposium on Macrocyclic Chemistry in 1977. The B.Y.U. group, including J. S. Bradshaw and J. D. Lamb, measured and complied equilibrium constants for cation-macrocycle interaction. They also synthesized many new macrocycles and developed membrane separation techniques for a variety of cations. C. L. Liotta, Georgia Institute of Technology, used crown ethers as the phase transfer catalyst for a variety of organic reactions in the early years. G. W. Gokel, University of Miami, created the concept of lariat ethers, which were crown ether derivatives with secondary donating sidearms. R. D. Bartsch, Texas Institute of Technology, developed effective extractant and carriers based on proton-ionizable crown ethers for alkali metal and alkaline earth metal cations. G. R. Newkome, University of South Florida, prepared new crown ethers that contained aromatic subcyclic units. R. Breslow, Columbia University is most famous in cyclodextrin chemistry. Recently, A. D. Hamilton, University of Pittsburgh prepared new macrocycles as synthetic receptors for nucleotide. C. D. Gutche, Washington University, received a great deal of attention in his calixarene chemistry research.

On the other hand, many Japanese chemists have also contributed to this chemistry. E Kimura, Hiroshima University, is the international member of this international symposium. He did an outstanding job in the field of azamacrocycles and was awarded the second Izatt-Christensen Award this year. Y. Murakami, Kyushu University, prepared a water-soluble cyclophane as a vitamin B_6-dependent holoenzyme model. I. Tabushi, Kyoto University, was one of the leaders in Japan in the field of biomimetic chemistry. K. Koga, Tokyo University, and K. Odashima, Hokkaido University, synthesized novel water-soluble cyclophanes and their inclusion phenomena for a variety of guest compounds. Koga and S. Sasaki, Kyushu University, used choral crown ethers as enzyme model for the synthesis of peptide. M. Takagi, Kyushu University, made chromoionophores based on crown ethers for alkali metal and alkaline earth metal cations. S. Misumi and T. Kaneda, Osaka University, succeeded in recognizing amines by coloration with azophenol-dyed crowns. T. Shono and K. Kimura, Osaka University, applied crown compounds to analytical and separation chemistry. M. Okahara, Osaka University, developed convenient synthetic procedures for simple crown ethers and reactive crown ethers. S. Shinkai, Kyushu University, prepared a variety of functionalist macrocycles such as switched crown compounds and water-soluble calixarenes. H. Ogoshi, Kyoto University, and Y. Aoyama, Nagaoka University of Technology, recently developed new macrocycles discriminating carbohydrates. H. Tsukube, Okayama University, clarified the transport abilities of multiarmed macrocycles across artificial liquid membranes. T. Hakushi, and Y. Inoue, Himeji Institute of Technology, found that the crown ethers with low symmetry often showed excellent selectivity toward a specific ion. Besides them, many researchers are interested in this chemistry.

Synthetic macrocyclic compounds now include crown ethers. cryptands, spherands, carcerands, cavitands, cyclophanes, and calixarenes and are expected to increase the kinds of macrocycles.

TOPICS PRESENTED AT THIS SYMPOSIUM BY THE UNITED STATES OF AMERICA AND JAPAN

E. Kimura from Hiroshima University is the recipient of the 1992 Izatt-Christensen Award. His recent work had involved the design of cation and anion receptor molecules, metalloenzyme models, molecular catalysts, transport agents and photo catalysis of carbon dioxide reduction. At his award presentation, he reported on the roles of zinc(II) in zinc enzymes on the basis of his model study using macrocyclic polyamine.

D. H. Busch from the University of Kansas, gave a plenary lecture on the attempts to perform O_2 oxidations within the cavity of a bicyclic cyclidene complex.

T. W. Bell from State University of New York at Stony Brook, presented a plenary lecture on the synthesis of new torands, which are preorganized host compounds that have macrocytic perimeters comprised of fully fused rings, and new uses for old torands. J. L. Sessler from the University of Texas at Austin, showed a new direction in porphyrin-related research concerning anion binding in his plenary lecture. Some of the expanded porphyrins have an ability to bind anions in their potential protonated form. Y. Murakami from Kyushu University, presented an invited lecture on molecular recognition by novel cage-type azacyclophanes containing choral binding sites in aqueous media.

The usefulness of mass spectroscopy in gas-phase studies of host-guest interaction was presented

by J. S. Brodbelt from the University of Texas at Austin. Similarly, D. V. Dearden from the University of Texas at Arlington, reported on the mechanism for the formation of a metal cation macrocycle complex in the gas phase.

R. A. Bartsch from Texas University, presented an invited talk on ionic recognition by proton-ionizable lariat ethers and their polymers. In collaboration with him, T. Hayashita from Saga University, reported on the synthesis and properties of dibenzocrown ether resins having various sidearm groups. C. M. Wai from the University of Idaho, reported on the application of lariat crown ethers containing carboxylic acid and hydroxamic acid moieties to selective extraction of lanthanides. R. D. Rogers from Northern Illinois University, reported on the crown ether extraction of group 1 and 2 cations in polyethylene glycol-based aqueous biphasic systems at high alkalinity.

L. Echegoyen from the University of Miami, presented and invited lecture on the electron transfer products between metals and C_{60}. K. E. Krakowiak from Brigham Young University, reported on a facile synthetic procedure for preparing cryptands. N. K. Dalley from Brigham Young University, presented an overview on solid state structures of host and host-guest compounds. S. H. Gellman from the University of Wisconsin, reported on the structure and complexation properties of macrocycles containing atoms from the second row of the periodic table such as sulfur and phosphorous. G. W. Gokel from the University of Miami, reported on bimetallic complexation by crown ethers, lariat ethers, and cryptands. E. F. Maverick of D. J. Cram's group from the University of California at Los Angeles, introduced recent advances in carcerand chemistry. E. V. Anslyn from the University of Texas at Austin, reported on polyazaclefts for complexing reactive intermediates. A. E. Kaifer from the University of Miami, reported on the synthesis and properties of asymmetric rotaxanes based on α-cyclodextrin.

C. D. Gutsche from Texas Christian University, gave a critical review on calixarene chemistry. The number of publications concerning the title compounds was demonstrated to sharply increase in a few years. Several related lectures were presented at this symposium.

The author from Osaka University presented an invited talk on the transport of metal ions in the opposite directions across an artificial membrane. The exchange between Na^+ and K^+ or between Ca^{2+} and K^+ was realized by pH control.

K. Kumar from Bristol-Myers Squibb Pharmaceutical Research Institute, reported on macrocyclic polyaminocarboxylate complexes of lanthanides as magnetic resonance imaging contrast agents. O. A. Gansow from the National Institute of Health, reported on the systematic radiation therapy of cancer by using radioactive metal macrocycles and chelate linked to antibodies. R. W. Taylor from the University of Minnesota, reported on complexation chemistry of ionophores A23187 and Ionomycin. B. E. Jepson from EG & G Mound Applied Technologies, reported on chromatographic enrichment of calcium isotopes with 18-crown-6 bound to a macroporous solid support.

IMPRESSIONS AT THE SYMPOSIUM

Upon my attendance at this symposium, I felt that the chemistry of macrocyclic compounds is more and more expanding its realm. In addition to crown ethers and cryptands, some other macrocyclic compounds such as expanded porphyrins and calixarenes have been demonstrated to be very efficient as the hosts for a variety of guest compounds. This series of symposia really provided an excellent place where each scientist of a variety of researches challenges the clarification of host-guest interactions and can present his/her own results. Although a major part of the contributions to this field of macrocyclic chemistry was really done by Americans, I would like to emphasize that some important contributions were from Japan, as shown in this report.

Dr. Yohji Nakatsuji received his B.S. (1974), M.S. (1976), and Ph.D. (1979) in Applied Chemistry at Osaka University, Japan. Since 1979, he has been a faculty member at Osaka University and is now an associate professor in the Department of Applied Chemistry. During 1984 and 1985, he worked with Professor Jerald S. Bradshaw at Brigham Young University as a postdoctoral fellow. He was awarded the Japan Oil Chemists' Award for Young Scholars in 1990. His research interests include the synthesis and cation complexation properties of macrocyclic compounds and the related open-chain analogues. He is a member of the American Chemical Society and the American Oil Chemists' Society.

SOUTHEAST ASIA REGIONAL COMPUTER CONFERENCE (SEARCC'92), KUALA LUMPUR, AUGUST 1992

Summary of the Southeast Asia Regional Computer Conference (SEARCC'92) held in Kuala Lumpur, Malaysia, 11-14 August 1992, and a general overview of the state of Malaysian information technology activities are presented.

David K. Kahaner

I wish to thank

Dr. Tengku Mohd. Azzman Shariffadeen
Director General, Malaysian Institute of Microelectronics (MIMOS)
Ministry of Science, Technology, and Environment
7th Floor, Exchange Square
Off Jalan Semantan Damansara Heights
50490 Kuala Lumpur, Malaysia
Tel: +60 3-255-2700;
Fax: +60 3 255-2755
Email: TMAS@JARING.ISM.MY

and

Professor Michael J. Olan
Computer Science Department
University of Wisconsin —
La Crosse, 131 Morris Hall
La Crosse, WI 54601 U.S.A.
Tel: (608) 785-6815;
Fax: (608) 785-8221
Email: OLAN@CSFAC.UWLAX.EDU

for many helpful comments, corrections, and additions to this report.

1. GENERAL COMMENTS MALAYSIA, HISTORY AND ECONOMIC SITUATION

This was my first visit to Malaysia. My impressions were very different from my expectations, the latter formed entirely by reading. I expected to see a third-world country, agriculture-driven, and visibly regulated by a strong Islamic fundamentalism. I can only report on what I saw, heard, and learned. As a result, my findings were quite different. Kuala Lumpur (KL), the capital, looks strikingly like what its southern neighbor, Singapore, must have looked only a few years ago. Large residential, commercial, and hotel constructions are everywhere. Ultramodern skyscrapers are adjacent to mosques, minarets, and cupolas. There are many weary structures, but also new department stores and slick malls. A large horse race-track complex in the center of the city is about to move to the suburbs. It will be replaced by a complex that will house the tallest building in Southeast Asia, over 90 stories high. A telecom tower is being built jointly with a German construction firm at a cost of Malaysian $250 Million (about US$100M); it will be over 420 m high, making it the third tallest tower in the world and the tallest in Southeast Asia. Streets and shops are full of people, and vehicles (there is no underground Metro—one major difference between KL and Singapore) such as buses are packed. Many Malaysian women wear the traditional Moslem black garments covering all or at least part of their faces. But many more wear bright colored clothing, western jeans, pants, and the everpresent tee-shirts. Stores are stocked with the usual cornucopia of Japanese electronics as well as clothing from famous houses around the world. Cafes are full of fashionable looking people drinking cappuccino and Perrier. The road between the capital and the airport (about 30 km) is lined with multinational factories. My taxi driver told me that the Hilton in the city was busy, but not as busy as the one near the airport, which is more convenient for international business people visiting their

Malaysian subsidiaries. (A new international airport is to be constructed about 40 km from the capital at an estimated cost of US$8B. The old airport will service only domestic flights. The new airport will be Southeast Asia's largest airport, even larger than the one in Singapore. It will be quite an accomplishment.) The road south of Kuala Lumpur going toward Singapore is new, multilaned, and spacious; however it is not completed all the way to the border. I was told that the roads in other areas as well as the ports are significantly underdeveloped. The energy and telecommunications systems' supply is outstripped by demand. There is substantial evidence of new building, and plenty of examples of agricultural development, primarily rubber and coconut palm plantations. The government has earmarked about US$40B for infrastructure, social development, and defense expenditure over the next five years. In most areas of economic development Malaysia leads Thailand, and the income per capita is almost twice as high.

Malaysia, formerly the British ruled Malaya, became independent in 1957. The country is ruled by a constitutional monarch elected for a five-year term by the nine hereditary sultans of the traditional Malay states. The monarch is chosen from among the sultans by the sultans on a rotational basis. Malaysia is composed of the southern half of the Malay Peninsula that connects, through Thailand, to mainland Asia, and of about half the large island of Borneo to the east. This island also contains a large Indonesian state and the tiny country of Brunei. Malaysia is populated by almost 18 million people, about 30% of these are of Chinese extraction, 9% are from India or Celon (mostly Hindus), and most of the others are Malay; almost all the latter are Moslems. The country is well endowed with natural resources, including lumber, oil, and natural gas. By Southeast Asian standards, Malaysia is large and not heavily populated—there is plenty of room for growth. British interest was focused on tin and rubber as well as shipping (tin exports now run at a rate of about US$300M, about one-fifth the amount obtained from palm oil.) The city of Malacca (150 km south of Kuala Lumpur) on the mainland's west coast was Portuguese, then Dutch, then British, and is situated at the juncture of trade routes between Europe and the Middle East. The adjacent Strait of Malacca is still one the world's busiest waterway.

Originally Singapore was part of Malaysia; only about one-half mile separates these two countries. The island of Singapore is at the southern tip of the Peninsula, but it was separated in 1965. The then Prime Minister of Malaysia agreed to the separation of Singapore because the Chief Minister of Singapore wanted certain freedoms that were not allowed under the agreement of federation, as for example education, which is a federal not a state matter. Even today many Malaysians feel that Singapore is a part of Malaysia and should not have been allowed to separate.

There are also distinct ethnic differences between Singapore and M. laysia—Singapore is over 90% of Chinese extraction. Indeed, there have been disputes between Malay and Chinese during the country's short history. The Chinese have focused on commerce and have been very successful, the Malays have dominated in the areas of agriculture and government. Since the early 1970s explicit government policy has favored Malays in education and, wherever possible, jobs, in an effort to give them a fairer share of their own country's wealth. Coupled with Moslem religious policies, this has created differences between Malays, Chinese, Indians, and Eurasians. Nevertheless, I was told repeatedly that all groups now live amicably. Some Malaysian experts feel that racial tension in the United States and England is worse than it is in Malaysia; some people would even go as far as to say that Malaysia is a role model for racial harmony. None of these people would claim that there are no problems, however, the problems are being tackled in an enlightened and fair manner. Certainly the government realizes that at least in the area of industrial progress it must use all the human resources available; and a senior official recently pointed out that "In many developing countries, political stability and national unity were never emphasized. It is important that national leadership integrate political, social, and economic factors in the quest for modernization." The Far Eastern Economic Review notes that the Malaysian "government will deemphasize its long-espoused goal of redistributing 30% of the nation's wealth to...Malay majority by a specified date... [and] will be less inclined to provide a free ride to [any] class."

Recent growth has been very strong, averaging about 8% annually since 1980. Unemployment is just over 4%; it is considered to be a full employment situation; however, a shortfall of more than half a million workers is predicted by the end of the decade. Rapid growth has generated a modest amount of inflation, about 4%, and the country has a weak balance of payments position, the latter fueled by

increases in consumer spending and foreign investment. The manufacturing sector claims that its labor pool is already short by 80,000 workers. Many foreign workers, including more than half a million from Indonesia, are employed illegally. At the same time, higher salaries and opportunities elsewhere are attracting skilled Malaysians to move out of the country. This is a situation that Korea, Taiwan, Hong Kong, and other rapidly developing countries in the region have also faced. However, this seems to be self correcting, since many of these people are returning to their homeland in senior positions now that the economic outlook is brighter.

As mentioned above, many Western companies are in Malaysia, and investment from outside Malaysia is very strong. More than US$6.5B were invested in 1990, when France and Australia were involved in two large refinery projects. Taiwan has been Malaysia's largest investor, since 1987 almost US$5B were invested even though the rate has been reduced recently, partially because Taiwan is currently focusing on mainland China, and also because a US$3B steel plant project is still on hold. There is also a political problem concerning the impact of Taiwanese (Chinese) capital on the government's plan to distribute national wealth more equitably. However, the prevailing attitude is that "It doesn't matter where the money comes from," or more directly, "growth will take precedence over distribution." The Malaysian government appears to have adopted a pragmatic view. While I was there, Motorola celebrated its 20th anniversary in Malaysia; it has invested more than US$350M there. At the same time the company's Malaysian subsidiary has been given the task of spearheading the entry into PR China. Motorola records substantially more than US$1B in turnover at four manufacturing facilities here, between 20 and 30% of the company's global output.

Malaysia will spend a great deal of money in developing its R&D if current plans are implemented. By the year 2000, the country plans to spend 2% of its GDP (gross domestic product) on R&D, and 1.5% by 1995. Most of this increase should come from the private sector whose contribution is predicted to increase to about 60% of the total R&D expenditures. Five priority sectors have been identified,

(1) biotechnology,
(2) automatic manufacturing,
(3) advanced materials,
(4) electronics, and
(5) information processing.

The current budget allocates about Malaysian $600M (US$250M) to strengthen the existing R&D institutions and promote joint research among private, university, and government institutes.

Four other anecdotal examples of recent activities are given.

(1) NEC has recently been awarded a US$6.3M network system order. NEC (Nippon Electric Company) will deliver three 3400/65 mid-size mainframes and more than 250 workstations and will connect them into a network linking four major customs office centers across Malaysia. In addition to building up a network infrastructure, the system is claimed to be needed to handle the country's expanding trade and the influx of foreign capital. This is NEC's largest order to a governmental agency in Southeast Asia. NEC is also working to build an ISDN (Integrated Services Digital Network) switch in a new international telecom gateway.

(2) A very interesting joint Malaysian-Australian aircraft project, the Eagle X-TS, will be delivered this December along with about 75 aircraft that should be built in 1993, and 450 more by 1997. The Eagle X-TS is a three (sic) flying surface aircraft, with one large *wing* above and behind the cockpit and a smaller one below and just behind the single front prop. The Australian partner claims that this is its first project to use advanced composite materials technology. The Malaysian company is a joint venture between the Malaysian government and Petronas, the Malaysia's petrochemical company.

(3) Malaysia's Prime Minister will lead a trade delegation to Vietnam. The first ever such visit to Hanoi since Malaysia gained its independence in 1957.

(4) There is even an automobile industry in Malaysia. With the help of the Japanese, Malaysia's national car, the Proton Saga, has been on sale since 1985. Nearly 400,000 cars were sold in Malaysia, New Zealand, Singapore, and Britain; this summer a new model was launched.

During the week of the SEARCC'92, Malaysia was also running a congress and seminar on science and technology, which focused on the year 2020—a key date in government action plans and recommendations set forth in R&D related policy papers. Five major topics were selected:

a) Medicine,
b) Agriculture,
c) Social,
d) Industry, and
e) Strategic.

Each of the last two include the following.

Industry: Product, Service, Processing, Technology
Strategic: Energy, Environment, Advanced Materials, New Techniques

I did not participate in this meeting, but I was told that a report will be compiled and presented to the National Council for Scientific Research and Development (NCSRD). Interested readers can contact:

Urusetia Kongress and Seminar S&T Kebangsaan KE-6
d/a Kompleks PUSPATI, Bangi
4300 KAJANG, MALAYSIA
Tel: +60 3-825-0510
Fax: +60 3-825-8262

See also my remarks about Singapore, Malaysia's southern neighbor, at the end of this report.

2. SOUTHEAST ASIA REGIONAL COMPUTER CONFERENCE, 1992

This was the 11th annual Southeast Asia Regional Computer Conference, attended by about 650 delegates. SEARCC is composed of computer professionals from eleven countries, Pakistan, India, Sri Lanka, Thailand, Malaysia, Singapore, Indonesia, Hong Kong, Philippines, Australia, and New Zealand (NZ joined in 1991). Its main aim has been to allow Information Technology (IT) professionals to meet and share information. SEARCC is not primarily a research conference on computer science, although some research activities are featured. This year's conference theme was "IT Building Information Infrastructure for National/Regional Growth." Thus, the focus was on those aspects of computing that will have a broad impact and the importance of information technology in the progress and development of member countries. This includes many business related topics such as commercial information services (Electronic Data Interchange, Open Systems, and Value Added Networks). It also includes infrastructure topics such as security, education, standards, policies, as well as general management and human resources issues. Other buzzwords were object oriented technology, networking, and telecommunications. Thus, the majority of the presentations made at the conference touched upon these topics and their role in human development. (Some comments about the basic questions associated with this theme are detailed below.) Associated with the conference was an exhibition that drew more than 20,000 visitors, as well as the meetings of SEARCC Regional Interest Groups (SRIGs). Eight SRIGs have been identified. During this conference papers were presented on education, standardization, and telecommunications as part of the SRIGs. In addition there was an international computer programming competition for student teams from SEARCC member countries. The conference was held at the World Trade Center in Kuala Lumpur, which is up to international standards in terms of all facilities. A two volume Proceedings (in English) is available from the publisher. A list of titles and authors is attached to this report and I will distribute copies of selected articles to interested readers as time permits.

Publisher:
Gabungan Komputer Nasional Malaysia
Malaysian National Computer Confederation (MNCC)
46A, Jalan SS 2/66, 47300 Petaling Jaya,
Selangor Darul Ehsan MALAYSIA

The ten countries of SEARCC have a wide ranging socio-economic structure and capability (see tables below). Agriculture is still a very significant industry, especially with respect to the number of workers. Services are important, and value-added is low in most sectors. All the countries need vast improvements in human development services such as education and health. Research and development is generally weak (with some exceptions) as are the telecommunications and data services infrastructure (again with some exceptions). In the area of IT, consumption is very low compared to that in the United State or Japan, and the focus is on hardware. Most hardware is exported (86%), and the region is very weak in software production and information services.

In Malaysia, the 1990 electronics industry output was US$8B, which accounts for 18% of the

country's GDP, and 25% of its exports. This industry has had a compound growth rate of 22% since 1978. The computer industry forecasts sales in 1992 amounting to US$775M, with only about one quarter in software or services, and the rest in hardware with a per capita consumption of less than US$50. In other words, the electronics industry in Malaysia is important, but not yet as a source of IT development primarily because indigenous R&D is insufficient.

The opening SEARCC session included a keynote address by Academician B.L. Sendov (Bulgaria), President of IFIP (International Federation for Information Processing,) who discussed the somewhat enigmatic topic of "Data, Information, Knowledge, and Wisdom." The main premise of the talk was that while computers are far superior to humans in processing data into information, it is still in the realm of humans to be able to process knowledge in a way that produces what we refer to as wisdom. The address was highlighted by a live video conference between participants of SEARCC'92 and Professors Rubenstein and Leeburg at UCLA, organized by Telekom Malaysia. (This is the recently privatized telephone company that is now trying to develop products and services that consumers want. Their latest, Smartfon, uses a direct wireless base station link from a subscriber's handset to the public switched telephone network allowing calls to be made but not received. The motivation here is to duplicate the very rapid subscriber growth seen in Hong Kong and Singapore.) In my opinion, the primary motivation for the teleconference was to demonstrate the technology. For large conferences like this one, there is little audience interaction with the speakers—the session was essentially a lecture—and having an expensive video link requiring one group to be awake in the middle of the night appears to be overkill. A simple videotape would have been just as effective. A video conference is most useful when the participants need to be truly interactive.

The remainder of the first plenary session included talks about networking. The most significant fact presented was that networking provides the key to information sharing and access to large international information networks, e.g., internet and databases, which is crucial for developing countries.

I found that many of the papers, not unexpectedly, were of a very general nature, on *soft* topics, papers describing products or soon to be introduced products, introductory papers, etc. I was less interested in those and confined my remarks to the more technically oriented presentations. But, to be fair, many papers were of specific interest to members of the audience who were working in related application areas. In my opinion, some of the best papers described problems and trends of specific countries. It is clear that all the countries in the region see IT as a core technology for social and economic growth and are working diligently to build the infrastructure to support this. Everyone admits that IT has the potential to enhance other industrial sectors such as agriculture, manufacturing, etc. A key technological aspect of this relates to telecommunications and networking. Another aspect is human resources, there simply are not enough trained technicians and scientists, and education and training are seen as important needs. In some ways all of SEARCC'92 was a pep-talk for IT, with numerous statistics cited to show its growing importance, and repeated references to the MITI 2000 (Ministry of International Trade and Industry) report with extrapolations suggesting that the information industry could account for as much as one fifth of Japan's GNP (gross national product) by the year 2000, and the labor force involved in IT will be three to four times the 1984 levels. There is no doubt that IT will be one of (or maybe the) key industry in the next century, but I suspect that at SEARCC'92 these kinds of papers were *preaching to the choir.*

One Malaysian paper is worthy of note, if only to illustrate the state of current thinking. Scientists from the Mechanical Engineering Department of the university of Technology, Malaysia presented the results of a numerical simulation of 2-D air flow in an enclosure with heated walls. The SIMPLE (Semi Implicit Method for Pressure Linked Equations) method was used for solving the discrete equations, but the main point of their paper was to demonstrate the integration of various existing analysis tools, including a Fortran fluid flow solver, SAS for producing contour plots, and AutoCad for other plots. The authors conclude "We have shown that there is a need for an integrated engineering analysis system... [to] provide engineers with an effective tool to design and operate engineering systems... This may be accomplished by converting the data generated into a format that can be exported to any engineering package." This is true, and in the West is accepted practice within the engineering community.

The conference proceedings included the text of about twenty papers, including the one above, that

were not presented at SEARCC'92. Most of these were research papers and included reports on imaging systems and natural language processing from Malaysian scientists, an interesting computer graphics paper from Singapore, and a generalization of an encryption scheme (proposed by Davida, Wells, & Kam and known as DWKC) by Taiwanese scientists, which replaces the Chinese remainder theorem with an algorithm based on Galois fields. Because these papers were not presented there was no mechanism to allow discussion with their authors.

One afternoon track was devoted to eight research papers. This session was a last minute addition, urged on the organizers by colleagues at the National University of Singapore (NUS). Because of scheduling, all but one of the speakers were from that country and, disappointingly, there were no Malaysian speakers. In addition, the papers were not included in the Proceedings, although one paper was made available to us on the last day of the conference. (Frankly, I couldn't distinguish between some of the better papers given in the Proceedings but not presented, and this set, presented but not in the Proceedings.) Most SEARCC attendees took the opportunity to participate in an industrial tour, but those few dozen who stayed were extremely surprised to discover that most of the research papers were of excellent quality, in fact among the most coherent and clearly presented work at SEARCC'92. Several of these presentations were of as high a quality as those given at conferences in the United States and served as an indication that significant research is being done in parts of the Southeast Asia region. For the more technically minded, this session was one of the highlights of the conference, and I expect that this component will receive expanded coverage in subsequent SEARCC conferences. (Next year's SEARCC will be held in Hong Kong, 5-8 October 1993, as part of that country's week-long IT exposition.) Without written papers, the oral presentations (20 minutes) were sketchy; however, a few are described below.

Three of the most interesting of the research papers were presented by

Prof Hon-Wai Leong
Dept of Information Systems & Computer Science
National University of Singapore
Lower Kent Ridge Road
Singapore 0511
Tel: +65 772-2903
Fax: +65 779-4580
Email: LEONGW@ISCS.NUS.SG

and his collaborators at NUS. Leong who obtained his Ph.D. at the University of Illinois, explained that there are two main groups in his department, Algorithms, and VLSI (very large scale integration) Design Automation, but that there is good interaction between them. For example, interest in robot motion planning can be related to VLSI routing, which in turn relates to computational geometry. He described the problem of a point robot in a 2-D static environment with obstacles and free regions (all rectangular) and only horizontal or vertical motion allowed. Associated with this are problems of finding the shortest total length path, the path with minimum number of bends, etc. All of these are being studied within his group by using various graph, tree search, and line search algorithms. ("Geometric Algorithms for Rectilinear Path Problems and their Applications)". More general problems of finite size robots and simultaneous movement of more than one robot are also being examined. Leong described work associated with reconfigurable memory (RRAM) or processor arrays ("Efficient Algorithms for Reconfiguring VLSI/WSI RRAMs by Row/Column Deletion.)" By introducing structural redundancy it is possible to enhance the yield and improve the fault tolerance of these devices. Given one or more bad processors, the goal is to find a good repair solution (e.g., replace one processor with a spare) or decide that the available spares are not configured in a way that will make repair possible. With realistic constraints (finite number of spares, etc.) this is known to be an NP-hard problem (Konig Egervary Theorem,) but Leong and his group have developed heuristic to speed up the algorithm, developed a new test for irrepairability, and performed a probability analysis for perfect (alpha, beta) covers. He claims that their new algorithm is very efficient for RAMs.

In a related paper ("New Results on Channel Routing,)" Leong's colleague K.K. Lee briefly described a new channel routing algorithm for reducing the number of *vias* (layer changes) and space between distinct chips, and claimed that this was an improvement on the bubble sort router developed by Chaudhary and Robinson. Details are to be presented at the Asia Pacific Conference on Circuits and Simulation, December 1992.

Other papers to be presented in this session include Loh Wai Lung (NUS), ("Some Specifications for Object-Oriented Systems,)" Sally Jo Cunningham, Waikato U, New Zealand, ("Learning Rules by Example: Finding the Rules Hidden in the Data,)" Hong Jun Lu ("Least Fixed Point Computation in Deductive Database,)" K.P. Tan, NUS, and ("Pyramid Grid Sort.)" Finally, Chin Wei Ngan (NUS) presented a splendid survey (" Optimizing Functional Programs,)" i.e., no GOTOs, no global memory, no assignment statements.

One invited presentation to the general conference on Massively Parallel Computers was by

Professor L.M. Patnaik
Dept of Computer Science & Automation
Chairman, Microprocessor Applications Laboratory
Indian Institute of Science
Bangalore 560 012 India

Although through no fault of Patnaik, this paper was out of place at SEARCC. (In addition he had dozens of slides and was only given about 25 minutes. When combined with typical Indian rapid-fire English and no printed manuscript it was doubtful if many of the Malaysians were able to follow him.) He presented a good overview of the need for, and capabilities of parallel computers, their history, and described in detail the ICL DAP, and the Thinking Machines CM-1 and CM-2 (all machines that have been superseded by newer models,) concluding with a discussion of how parallel computers can be used to simulate neural networks. I have remarked in other reports, that India has an active parallel processing research program; Patnaik's paper was an indication that Indian scientists are carefully monitoring developments in this field.

Although not really considered as research papers, there were presentations of various aspects of object-oriented technology. The conclusions drawn are that object oriented techniques are being applied to the analysis, design, and implementation of a wide variety of information system projects and it appears that these methods will dominate development projects for some time to come.

It is difficult to generalize about a large conference such as this, but a few points stand out.

(1) **Open Systems**—Malaysia has officially embraced Open Systems for public sector procurements. This means that government agencies that are planning to purchase computer systems, software, etc., can specify their requirements in terms of various IEEE, ANSI, and ISO standards for general principles, operating system interfaces, programming languages, commands, utilities, networks, device interfaces, data management, interchange and compression, databases, user interfaces, security and system development methodology. They can then expect vendors will be able to comply on the basis of satisfying the standards set forth in detail in these documents. MAMPU (Malaysian Administrative Modernization and Management Planning Unit), the prime agency responsible for promotion, usage, and control of IT in the public sector has issued a detailed booklet that explains the steps that government organizations should follow during their procurement and requirements specifications. At the moment, agency participation is voluntary, and specifications are stated as being recommended, preferred, or optional. Nevertheless, this is really a different situation from the one in Japan, where Open Systems have not been as healthy as their proponents would like.

In general, open systems attracted a lot of attention at SEARCC 1992, and numerous presentations addressed issues related to this topic. Talks ranged from those touting the benefits of their particular open systems products to a panel discussion of the pros and cons on open systems. At SEARCC, senior managers from both OSI (Operating Systems Interfaces) and the Unix community made presentations. Their key points were that the Unix/OSI wars are over, and that the organizations appreciate their need to cooperate to survive in the future. (Let's hope so.) Repeated comments were made about the relative number of MS-DOS vs. Unix systems indicating that Unix/OSI supporters have to work together. While conclusions are difficult to make because of the wide variety of views, there is no question that open systems will play a major role in IT development in Southeast Asia, and several governments already give their support to open systems projects. At the R&D level, W. Coelli (Queensland University) stressed that an OSI compliance test center was badly needed in Asia. Further evidence of the impact of open systems in the region was the IT Expo held in conjunction with the conference. This large exhibit featured over 20 vendors taking part in an interoperability demonstration of their respective systems and was one of the most crowded exhibits.

(2) **Research**—The number of the research population in Malaysia is very low, only 330 per

million people, compared to 4500 in Japan, 3850 in the United States, and 2700 in Germany. Opportunities and money are the best ways to improve this number. For example, various science and technology prizes offered by the government have essentially been doubled, and the National Science Award is about US$20K. Nevertheless, lack of research papers (especially from Malaysia) was one complaint that I had about this SEARCC.

(3) **Software vs. hardware in Southeast Asia**—This tack was hammered on by Dr. Stan Shih, the founder and Chairman of Acer Co.. This is Taiwan's largest computer company (more than US$1B in sales in 1991) and the most respected Asian computer maker outside Japan. The Acer Co. makes a line of PC and workstation products that include Unix boxes, laptops, and 486s. Shih's strategy for economic success is to move away from hardware and go into software. He pointed out that for the past ten years developing Asian countries have concentrated heavily on the development of PC related hardware, to such an extent that this part of the world is now one of the world's leading PC hardware manufacturing center. However, intense competition among PC hardware manufactures will reduce profit margins, and the future lies in the development of value added software, primarily in an open system environment. He detailed several specific steps:

(a) Develop highly focused and niche products first, such as firmware bundled products (to take advantage of the existing hardware expertise,) concentrate on the regional markets in Asia and use the PC marketing channels already operational for exporting software. Regional market penetration can occur by forming strategic alliances with multinational companies. Shih feels that Asics present a very specific new opportunity in the software business. He also noted that Taiwan's Computer and Communication Laboratories of the Industrial Technology Research Institute (ITRI) is in a consortium with Sun, and the Taiwanese companies Tatung, Acer, Twinhead, and Mitac for R&D in Asic, SPARC workstations, and controllers for video graphics, peripheral buses, and DRAMs.

(b) Cultivate software experts by training more people. Enlist government support in training personnel from academia or industry in the development of highly specialized products. Establish software development centers in countries with existing software manpower to make use of the experience gained from their past achievements. Promote the domestic software industry. Shih comments that in Taiwan the target is of US$6B in software production revenue by the year 2000, and that a software industrial park will be established to accelerate the development of the country's local industry and create a world-class brand name. (Under Taiwan's recent National Development Plan, the country's IT industry has secured US$18B in funds that are directed towards speeding up technology development, increasing R&D projects, and improving manufacturing capabilities of computer makers.)

(c) Attract well known software houses and companies for local investment by offering incentives. Shih believes that the transfer of development technology from these companies would push software produced in Asia forward to world-class standards sooner than by continuing to produce software independently.

(d) Other strategies include joint ventures, strengthening intellectual property rights laws, and enforcing copyright protection.

Shih concluded by summarizing that,

- Asia's new opportunities are in the software business
- Asia's future is in Open Systems

"Most importantly, is the formulation of long-term development strategies, creative and customer-driven marketing, product quality improvement, strong product support, and continuous product research and development that will make us a world-class competitor." In my opinion, this kind of philosophy has no relation to what one normally associates with Asian software. If it is implemented, watch out Microsoft!

In terms of vision and philosophy, I was very impressed by the remarks made by MIMOS's Dr. Tengku Mohd. Azzman Shariffadeen (address given above). He pointed out, again, that most SEARCC members are weak in the R&D area. Malaysia in particular is strong in the electronics industry, but not in R&D. Dr. Azzman commented that the conference theme leads to the question of which R&D programs have the potential to lead to a better information infrastructure (hence to growth), how do we conduct these programs, and how should regional opportunities for collaborative R&D best be exploited? His list of strategies sounded surprisingly like Shih's—collaborative R&D, strategic alliances, competition with cooperation, need for standards

(OSI), intellectual property rights, regional products, intraregional flow of skilled personnel, computer networks for information flow. He also mentioned, very briefly, several specific Malaysian R&D programs including:

- Computers in education
- Joint Advanced Research and Internetworking Project (JARING)
- Rural telecommunication
- Natural language processing
- SCADA
- Machine intelligence

Some additional details about JARING and machine translation projects are included below. SCADA stands for supervisory control and data acquisition system. The first version of this product was installed to monitor and control a set of electric power substations in a portion of Malaysia, but other applications are now being developed. Azzman made one final point worth noting because it may conflict with other peoples's opinions. He pointed out that the IT industry, in Southeast Asia, may not be important for its own sake, but mostly for the opportunities that exist in applying IT to enhance growth in other sectors of the economy. Key technologies seen to be associated with IT are Telecommunications, Client/Server Cooperative Processing, Multimedia and Human Computer Interface, Object oriented processing, and CASE (Computer Aided System Engineering).

Finally, Azzman emphasized the potential for IT to enhance human development, and the importance of people. This point was highlighted by him, not only at this instance, but numerous times at this conference by repeating, "invest in technologies that invest in people", "emphasize user training", etc.

JARING is a new project meant to establish an integrated, nationwide data communication network based on recognized international standards. Other goals are to stimulate R&D, and provide a platform to study and evaluate data communication technology. Plans are to provide common network services such as electronic mail, bulletin board, FTP, and remote login. Users and researchers will define their needs; basic technology is to be provided by equipment and telecommunication service suppliers; and MIMOS will match these two, e.g., provide the administration and oversight. For further information either contact Azzman or send email to JARING@RANGKOM.MY.

3. SEARCC'92 EXPOSITION

More than fifty organizations were represent at the heavily attended exposition that accompanied SEARCC'92. Mostly, these were vendors demonstrating Open System applications and PC/WS commercial hardware products. The PC clone business was slow, and several vendors were offering 386 and 486 systems almost at "fire-sale" prices. They even threw in a computer table or other equipment as encouragement. (Malaysia is primarily an assembler of PCs, but there is one large manufacturer of PCs that designs and manufactures them locally—Micro Computer System. This company recently won two large orders to supply Unisys as well as the Olympia group of Germany.)

One exhibit that was particularly interesting showed the work at CICC (Center of the International Cooperation for Computerization). This is a nonprofit organization founded about ten years ago by the Ministry of International Trade and Industry (MITI) of Japan. Its purpose is to implement cooperative activities promoting computerization in developing countries. This involves: Education and training for trainees from abroad to learn to develop software instructors, engineers, and microcomputer engineers technical guidance and consultation by dispatching experts abroad; information services such as local seminars, promotional materials, texts, and movies; studies of computerization, information systems, current status, policies, problems, cooperative studies on machine translation; information exchange, invitations for people exchange, international conferences, communication links with international organizations. More than 50 Japanese companies participated and there were activities by almost twenty countries. Education was a major part of CICC efforts, especially conferences and training. Examples of conferences were "International Conference for Computerization '91" (Tokyo), "Fifth Asian Forum for Standardization of Information Technology" (Tokyo), "Sixth Asian Forum for Standardization of Information Technology" (Malaysia); various conferences between two countries about computerization cooperation were shown such as between Egypt-Japan, Saudi Arabia-Japan, Malaysia-Japan, and Sri Lanka-Japan, computer aided instruction workshops in China, Thailand, Philippines, and Malaysia. CICC supports SEARCC conferences, computerization essay contests; it gathers statistics of computer utilization and penetration, and conducts

surveys on IT standardization. Training activities typically involve a large number of countries with a few (rarely more than half dozen) students from each country. Training can be in the home country or in Japan.

CICC's main cooperative research activity lays in a machine translation system for Asian languages (currently Chinese, Thai, Indonesian, Malaysian, and Japanese). This work has been in progress since 1987 and will run through 1993. In Japan it involves researchers at ETL, CICC's Machine Translation System Laboratory, the Japan Electronic Dictionary Research Institute, and various computer manufacturers and software houses. Each of the four other countries also have a research institute associated with the project. CICC has contributed over US$3M toward the project. The main approach is to pre-edit the text to make it easier to translate, then follow it by morphological, syntactic, and semantic analysis, and eventually convert it into interlingua by using the rules of sentence analysis grammar. In other words an intermediate language is used as the pivot for translation. From this and by using the dictionary, sentences are generated in the target language. The main applications are to translate technical documents at high speed. In Malaysia, this project is being conducted jointly at three universities; University of Technology Malaysia, University Sains Malaysia, and Dewan Bahasa dan Pustaka. (Professor Henk Schotel, University of Nijmegen [HSCHOTEL@KUNRC1.URC.KUN.NL,] visited Sains Malaysia on Penang Island recently, and "was amazed at the number of PCs and Macintoshes available to students and staff—there were hundreds of them. Now the first SUN work stations have arrived, and they are quite advanced users of the hardware. I visited PTMK (Projek Terjemahan Malalui Komputer) that aims at translating Malay into English. The project leader, Prof Zaharin [ZARIN@CS.USM.MY] is also the head of the whole Computer Science department and very internationally oriented.) On a related topic, S. Nirenburg (CMU) gave an invited paper on software tools developed at CMU for machine-aided translation, which implied that, given the state of current technology, humans still need to be in the translation loop.

CICC has a number of publications. Three of the more interesting are the following:

a. "CICC News". It appears several times per year, contains details of CICC activities, brief summaries of conferences, training schedules, and a calendar of computer related conferences in the region.

b. "Continuing Progress of Computerization in Japan '91-92". It describes the computer industry in Japan, and the present status of the Japanese software industry, trends in information service and IT in Japan, and two *new* developments, (a) Institute for New Generations Computers Technology (ICOT), (b) a project to integrate and computerize health and welfare activities, thus allowing single source management throughout the country.

c. "Textbook: 6th Asian Forum for Standardization of IT". Proceedings of a conference of the same name held 10 August 1992 in Kuala Lumpur. Although focused on Open Systems, this document is still very interesting, especially as it contains site reports from Malaysia, Indonesia, Japan, China, Philippines, Korea, Singapore, and Thailand.

Contact:

CICC
Mita Mori Bldg, No. 43
13-16, Mita 3-chome, Minato-ku,
Tokyo 108, JAPAN
Tel: +81 3-3457-0941
Fax: +81 3-3457-0944

4. STATISTICAL INFORMATION

Figures in the tables below were extracted from IT Asia, February 1992, which in turn extracted them from an ASOCIO report (Asia Oceanic Computer Industry Association) presented at the end of 1991. Some of the data were obtained from Taiwan's Institute for the Information Industry (III).

5. MEANWHILE, BACK IN SINGAPORE

Malaysia is trying to copy those aspects of Singapore's development that seem appropriate. There is no doubt that this little country has been a tremendous success, and is an inspiration to other countries in the region. Even during the current recession its economy has expanded at a real rate of 5% during the first half of 1992, and unemployment is only 2%. Inflation since 1974 has averaged less than 4% (U.S. average during this same period was about 6.5%). This year, it should be 2.5%, about one third of the average wage increase; 1991 per capita GDP was US$20,400, compared to US$14,900 in 1984 this corresponds to a GNP of US$13,271 in 1991. The future looks very bright, even if it is not

guaranteed. Economists have predicted that Singapore is very likely to be among the twenty richest countries in the 21st century. To do that it has to continue to focus on people and seven major industries:

- microelectronics,
- biotechnology,
- new materials,
- civilian aviation,
- telecommunications,
- robots and machine tools, and
- computers and software.

Success will occur if other countries in the region allow it to become the headquarters city for the area, and at the same time are themselves moderately successful.

Thus regional efforts need to be enhanced, and competition between countries in the region, while continuing at one level need to be friendly not adversaries. Singapore needs to have a strategy, and if anything, the country is good at high level coordinated planning. Often less developed countries can offer substantial perks such as cash or tax incentives to attract suitable investments. Countries like Singapore, on the other hand, need to have a sufficient pro-business environment to generate higher rates of return than less developed countries. An economic panel has been formed in Singapore, which has identified a number of strategic thrusts (these are very general and include enhancing human resources, promoting national teamwork, and becoming internationally oriented.)

Singapore's government has a very definite slant toward economic development, which was spelled out recently by the Prime Minister, Mr. Chok Tong Goh. "It is Singapore vs. other countries," "Singapore vs. the rest of the world." In other words, Team-Singapore, placed between Hong Kong's every man for himself, and New Zealand's state welfare approach. (New Zealand is singled out as a case of what not to do; a country that was the fifth richest in 1966, is now the 19th, while Singapore has gone from 33rd to 18th during that same period. Mr. Goh's explanation: New Zealand's ranking fell because its welfare subsidies increased the dependency of the people and sapped their competitive drive.) Mr. Goh emphasizes that the key to success is giving people incentives in order to strive, i.e., good pay and light taxes. (The starting tax rate is 3%, compared to 15% and 30% in Japan and Sweden, respectively. Half of Singapore's taxpayers, about 500,000, pay about US$100 or less in taxes.) Another aspect of Goh's plan is to make the people of Singapore asset owners. Currently only 14% of adults own shares in publicly listed companies (compare this with 21% in UK, and 27% in Japan); Goh hopes to increase that to 30% in Singapore. The government plans to sell shares in Singapore Telecom at a discount next year, and also plans to sell shares in the Mass Rapid Transit, Port of Singapore, and a new company formed to run the country's electric and gas departments.

There are some worrisome signs however, and it is doubtful that Singapore will reach its target by achieving Switzerland's 1984 per capita income (US$31,800) by 1999. To do this would require 7% real-economic growth for the remainder of the decade; however; this is unlikely to occur since the days of double digit growth are probably over. Pressure from below, other developing countries, as well as above, the North American Free Trade Area and European common market will make growth more difficult. Mr. Goh comments, "we have to make the effort and not take the route that some other countries took trying to avoid this arduous climb upward. We don't promise a good life without expecting you to make the effort." But, "I can promise to make every Singaporean who completes 10 to 12 years of education, middle-class and asset-owner."

6. CHIP SALES

Comments from key ASEAN computer experts about the need to move from hardware to software should not obscure the fact that demand for semiconductor chips in Asia-Pacific is still very strong. Estimates are that chip sales will be over US$9B, up and above 20% in the region in 1992, excluding Japan, will be about US$11B in 1993, and US$17B by 1996. This year's current sales are equal to those in Europe and are expected to be greater within a year or so. Most of the chips are bought from outside the region as the indigenous industry is not large enough to satisfy demand. (United States companies such as TI, HP, and Motorola, are rapidly setting up chip-making facilities in Taiwan, Singapore and other countries.) Chips that are now made locally are mostly memory chips for PCs, and most of these are exported. Korean and Taiwanese companies have a particularly hard time. For example Korea exports 90% of the chips it produces and has to import almost as many other kinds (US$5.7B

vs. US$4.8B.) For example, Samsung sold 93% of last year's semiconductor output to the export market, 5% to its affiliated companies, leaving very few to support production needed for company products (Samsung supplies 14% and 9% of the global market microwave ovens and videocassette players.) Thus, a natural conclusion is to expect a large ramp-up in the local manufacture of chips to be included in products produced locally. (Statistics are from the "Far Eastern Economic Review," of 10 Sept 1992.)

Dr. David K. Kahaner joined the staff of the Office of Naval Research Asian Office as a specialist in scientific computing in November 1989. He obtained his Ph.D. in applied mathematics from Stevens Institute of Technology in 1968. From 1978 until 1989 Dr. Kahaner was a group leader in the Center for Computing and Applied Mathematics at the National Institute of Standards and Technology, formerly the National Bureau of Standards. He was reponsible for scientific software development on both large and small computers. From 1968 until 1979 he was in the Computing Division at Los Alamos National Laboratory. Dr. Kahaner is the author of two books and more than 50 research papers. He also edits a column on scientific applications of computers for the Society of Industrial and Applied Mathematics. His major research interests are in the development of algorithms and associated software. His programs for solution of differential equations, evaluation of integrals, random numbers, and others are used world-wide in many scientific computing laboratories. Dr Kahaner's electronic mail address is: kahaner@xroads.cc.u-tokyo.ac.jp.

PACIFIC RIM INTERNATIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE 1992, SEOUL, SEPTEMBER 1992

The second Pacific Rim International Conference on Artificial Intelligence '92 (PRICAI'92), held in Seoul, Republic of Korea, 15-18 September 1992, is summarized in this report. An assessment of the general trends of Asian AI research is also given.

David K. Kahaner and Thomas Weigert

This report is coauthored by Kahaner and Professor Thomas Weigert.

PACIFIC RIM INTERNATIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE 1992

The second PRICAI conference was held in Seoul, Republic of Korea, from September 15 through 18, 1992. The conference venue was the Lotte World Hotel, a huge complex containing not only an international class hotel but a Korean version of Disneyland, department store, ice rink, swimming pool, and other attractions. This is on the south side of the Han River in a new part of Seoul, which has been developed in the years after the Korean war. Visitors in this part of the city unanimously notice the vast tracks of high-rise apartments. This is one attempt by the government and private developers to ease the very tight housing situation in Seoul.

The global economic slowdown has certainly affected Korea, and virtually every major business group has been in a slump. Many are scaling down or scrapping their planned facility investments that were scheduled for this year, and almost all will fall far short on projected targets in these areas. While this includes facility expansion, it does not seem to include R&D investments. In fact, most companies seem to be implementing their R&D projects more or less as scheduled. Some examples follow.

Daewoo facility investments in the first half of the year were less than 40% of their annual goal, but R&D investments were on track. Similarly, Hundai has only spent about 40% of its projections for general facilities investments but almost all of its projections for R&D investments. Roughly equal reports have come from other large Korean companies, including Samsung, Lucky, Goldstar, Pohang Iron and Steel, etc.

The slump has not put much of a dent in large infrastructure investment plans of the Korean government however. These include a high-speed rail link that will connect Seoul with Pusan (420 km), a new international airport, and development of port facilities at Kwangyang, which is about 120 km west of Pusan, in order to reduce congestion at that port. Planners believe that the future of Korean competitiveness is at stake in these projects. The rail line is particularly interesting, as the contract will shortly be awarded to a company from Germany (Siemens), France (GEC Alsthom), or Japan (Mitsubishi), which will then participate in technology transfer to three major Korean companies, Hyndai, Daewoo, and Hanjin.

Readers should also note that plans for the Taejon Expo '93 Korea, which were mentioned in an earlier report ["korea.312", 13 March 1992,] are progressing. Taejon is Korea's science city, about two hours by train south of Seoul. The Expo will have a permanent exhibition site with pavilions from the largest Korean companies or industry groups,

including such things as Mag-Lev, Electric vehicles and pilotless ground surveillance airship. Scheduled to last three months, Aug—Oct 1993, this would be a good time for a visit.

PRICAI'92 was jointly hosted by the Korea Information Science Society and the Center for Artificial Intelligence Research (CAIR). The latter is part of the Korea Advanced Institute of Science and Technology (KAIST). Although the conference secretariat is probably disbanded, readers interested in copies of the Proceedings or other information, can contact

Dr. Soung-Soon Chun, President
Korea Advanced Institute of Science
and Technology
373-1 Kuseong-dong Yuseong-ku
Taejeon, Korea
Tel: +82-42-869-2001, -2101,
Fax: +82-42-869-4800

or

Prof Jung Wan Cho
Dean of Research Affairs
Computer Science Department
Korea Advanced Institute of Science
and Technology
373-1 Kuseong-dong Yuseong-ku
Taejeon, Korea
Tel: +82 42-869-8701, -2005;
Fax: +81 42-869-8700
Email: jwcho@cs.kaist.ac.kr

Readers can also contact me for copies for limited numbers of papers.

After the first PRICAI in Nagoya (1990), Japan, this conference has been hailed as the leading standing conference on Artificial Intelligence (AI) topics in Asia. Therefore, many researchers attended with the expectation of gaining a thorough overview of the state of the art in AI research in Asia. Perhaps this was an unreasonable expectation. Several outstanding papers were presented, and in general the research was adequate but not striking. Many of the leading researchers of Japan did not attend or present papers. Korean research is definitely improving, especially when compared to that presented at PRICAI'90. Key application areas were well represented, and careful work was evident in almost every subfield. With respect to the level of theoretical papers from Korea on topics not directly related to applications, we look forward to additional progress and deeper contributions.

PRICAI'92 also included a small exhibition of more than a dozen institutes and companies. Of these, the most interesting was from the Center for Artificial Intelligence Research (CAIR), part of the Korean Advanced Institute for Science and Technology (KAIST) that showed, among other things, their work on a pen-based computer, and English to Korean machine translation environment (MATES/EK). KAIST is also working with NEC (Nippon Electric Company) on a Korean to Japanese translation machine, and at the PRICAI'92 this project was first formally announced. (Japanese companies as well as the Japanese government have been active in supporting machine translation within Asia. This is an investment that will return large dividends.)

From the list of participants we counted 306 attendees from 19 countries. Naturally, most participants were from Korea; Japan was second. From all the other countries, only 7 attendees did not present a paper. The following is a break-down of conference participation along rough geographical lines:

A significant number of no-shows were also present, mostly from the PRC and Europe.

(1) TUTORIALS

The first day was reserved for tutorials. These were primarily attended by students. Their abstracts are included at the end of this report.

(2) INVITED SPEECHES

Several invited talks presented surveys of some area of AI research. Here we mention three in detail, however the titles of all will follow.

S.-J. Hong of IBM gave a summary of IBM's yearly outlook for the next ten years of computing. He predicted that the current trends in hardware development will continue for at least the next decade: DRAMs will be at 4 GBit, flat panel displays will achieve printed page resolution (ultimately making all displays flat), storage device capacities will be at 10 GBit/in^2, reaching 2*10^17 bytes capacity by the year 2000. Communication speeds using fiber optics will reach 1000 GBit/s. Hong predicted that businesses will not be able to make money from semiconductors, and that the future of semiconductors lies in subsystem development and custom VLSI (very large scale integration).

	Attendees	Papers	
Korea	155	46	28%
Japan	73	47	28%
USA/Canada	36	36	22%
SE Asia/PRC	22	20	12%
Australia/NZ	11	10	6%
Europe	7	5	6%
S. America	2	1	1%
	306	165	100%

Generally, Hong felt that IBM's center of interest should move from the computer to the information industry. He commented that he has observed software business growth the from 30 to 40% a year during the last decade, with specific applications dominant. Applications written by users will need better user interfaces and natural languages. As far as CMOS microprocessors are concerned, cycle and transistor density trends will continue, and microprocessors will be the basic building blocks of every computer, including mainframes and parallel processors. Hong explained that his slides were part of a set that he used at an annual IBM planning meeting; and although he was allowed to project them, he was not allowed to distribute copies. This was disappointing, as they went by very fast.

Se June Hong
Senior Staff, Plans and Controls
IBM Research Division
T.J. Watson Research Center
P.O. Box 218
Yorktown Heights, NY 10598 USA
Email: hong@watson.ibm.com

J. Pearl surveyed current trends in approximate reasoning and sketched their move from numerical probabilities to qualitative beliefs. He pointed out that judgements about independence are at a deeper level than probability, and that three key difficulties are dealing with specificity, irrelevance, and causation.

Prof Judea Pearl
Cognitive Systems Laboratory
Computer Science Department
University of California
Los Angeles CA 90024
Email: judea@cs.ucla.edu

T.L. Kunii (University of Tokyo) presented an interesting summary of the challenges that face computer visualization. He showed impressive results obtained by using higher-level abstractions, such as homotype, singularity, and bifurcation models. We have discussed Kunii's ideas before. He has been working since the early 1970s and has coined the term *visual computer* in the early 1980s. In my opinion, he is a real visionary, but in reality there was not much overlap between his paper and the overall theme of this conference. Outside of Japan, AI is still catching up to the implications of the capabilities of new technologies for handling speech, image, and data.

Prof Tosiyasu L. Kunii
Kunii Laboratory of Computer Science
University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan
Tel: +81 3 816-1783
Fax: +81 3 818-4607
Email: b39756@tansei.cc.u-tokyo.ac.jp

TITLES OF INVITED TALKS

1. "Plausible Reasoning: Form Numerical Probabilities to Qualitative Belief" Judea Pearl (University of California, U.S.A)
2. "Managing the Expert System Process: Verification, Validation and Testing" Jam. H. Griesmer (IBM, USA)
3. "Reusable Intelligent Collaborative Hyper-media: the MUCH System" Roy Rada (University of Liverpool, UK)
4. "Computing and Computer: A Prospect for the year 2000," Se-June Hong (IBM, USA)
5. "What Visual Computer can do - The State of the Art and Challenges," Tosiyasu L. Kunii (The University of Tokyo, JAPAN)
6. "Multi Expert System for Pattern Recognition," C. Y. Suen (Concordia University, CANADA)

7. "The Use of AI in Environmental Management," Robert L. Moore (USA)

Dr. Thomas Weigert
RISC-Linz
Johannes Kepler Univ. Linz
A-4040 Linz, Austria
Email: weigert@mcs.anl.gov

is presently in Japan for one year doing research work. He is at

Machine Inference Section
Electrotechnical Laboratory
Umezono 1-1-4, Tsukuba-shi
Ibaraki 305, Japan
Tel/Fax: +81 298-58-5918
Email: weigert@etl.go.jp

FIRST INTERNATIONAL WORKSHOP ON CONCURRENT ENGINEERING PRODUCT REALIZATION (CIRP)

The First CIRP International Workshop on "Concurrent Engineering for Product Realization," was held 27-28 June 1992, in Tokyo, Japan and is summarized in this article. The results of the workshop, some background information about CIRP (International Institution for Production Engineering Research), and of the organization that provided the technical sponsorship of the workshop are also included.

David K. Kahaner

INTRODUCTION

The First CIRP International Workshop on "Concurrent Engineering for Product Realization" was held on 27 through 28 June 1992, at the Surugadai Memorial Hall, Chuo University in Tokyo, Japan, right after the International Federation for Information Processing (Working Group 3) (IFIP WG5.3) at the International Conference for Programming Languages for Machine Tools (PROLAMAT'92), was held in 1992 (see the report "prolamat.92", 19 August 1992). That report, and the first section of the current one, were written by

Professor Stephen Lu
Director of the Knowledge-Based
Engineering System Research Laboratory
University of Illinois at Urbana-Champaign
1206 West Green Street
Urbana, Illinois 61801 USA
Tel: 217 333 6662
Fax: 217 244 6534
Email:LU%PLUTO@PLUTO.ME.UIUC.EDU,
or LU@KBESRL.ME.UIUC.EDU

The workshop was organized by CIRP (in French: College International pour l'Etude Scientifique des Techniques de Production Mecanique; in English: International Academy for Production Engineering Research) Scientific Technical Committee in Design (STC-DN), and was sponsored by IFIP Working Groups: WG5.2, WG5.3, and WG5.8. This two-day invitational workshop was attended by 67 researchers and practitioners in the field of research; they were from 15 different countries in North America, Europe, and Asia. The distribution of industrial and academic participants was about 31% and 69% respectively. The U.S. Office of Naval Research (ONR) was the third sponsor of the workshop.

Developing useful, reliable, and economical products is the most challenging task in the engineering profession. Because of the increasing complexity of the products and the intense competition in the world market, product development practices have changed from being *centralized* to being *distributed*. The centralized approach relies on broad expertise of few individuals. It is relatively easy to manage, however, it is not effective for highly complex products. The distributed approach deals with complexities by dispensing different product development functions to a team of engineers, and each team contributes its special expertise to the product specifications. This practice allows complex products to be developed, but is very difficult to manage. As a result, it prolongs the development time and often results in suboptimal product quality and value. The situation worsens when the develop-

ment of products must incorporate nonengineering expertise to be competitive, and are thus developed by teams of engineers and managers from different organizations located at remote sites.

Recently, the concept of *concurrent engineering* has been proposed as a potential means to improve the product development, which is also called *product realization* practice. The idea is to simultaneously satisfy the functionality, reliability, produceability, and marketability concerns; to reduce the product development time (i.e., lead-time) and cost; and to achieve higher product quality and value. This new product-development approach emphasizes simultaneous consideration of various product life-cycle concerns at early stages to increase the competitiveness of products. Therefore, it is also called *simultaneous* or *life-cycle* engineering. It is important to note that the essence of concurrent engineering is not just to simply strive for real-time, parallel, and simultaneous actions in product development. Rather, it requires a seamlessly integrated, highly cooperative, fully communicating, and systematically coordinated *team approach* to solve complex *system problems* in product development. More specifically, the concurrent engineering challenges can be translated into the following four categories:

1. integration of complementary engineering expertise,
2. cooperation of multiple competing perspectives,
3. communication of upstream and downstream concerns, and
4. coordination of group problem-solving activities.

Although there have been many reports and papers describing research and development efforts and results in this area over the past several years, there have been very few open forums, where researchers and engineers can exchange lessons and experiences to build a systematic framework that can define the scope and direction of future research and technology development. The workshop was intended to serve as a common forum for establishing a framework foundation for the research and application communities of this newly emerging discipline. The workshop's goal was to provide an opportunity for researchers and practitioners from different parts of the world to examine this developing issue from cultural, organizational, and technical perspectives. By identifying current issues and future directions at this workshop, it is expected that a basis can be established for concurrent engineering for product realization, which offers many challenging research and development possibilities for production and information processing technology.

The idea for the Workshop began about two years ago as a result of discussions among several members of the CIRP. More than forty years of history back up CIRP that is the most prestigious international organization for production research. Its membership is represented by over 38 countries and the member are elected through nomination and election by the General Assembly. The key planning members of the workshop were:

- Professor Fumihiko Kimura
  Department Precision Machinery Engineering
  The University of Tokyo
  Hongo 7-3-1, Bunkyo-ku,
  Tokyo 113, JAPAN
  Tel.+81-3-3812-2111 ex.6455
  Fax.+81-3-3812-8849

- Professor T. Kjellberg
  Research Unit of Computer Systems in Production IVH/KTH Program, KTH
  Brineelvagen 81, Sweden
  Tel (46)8.21.03.61
  Fax (46)8.20.22.27

- Professor F.L. Krause
  Fraunhofer-Institut fur Produktionsanlagen und Konstruktionstechnik - IPK
  Pasxalstrasse 8-9, 1000 Berlin 10, Germany
  Tel (030)39006243
  Fax (030)3930246

- Professor S. Lu
  (U.S.A, address given above)

- Professor G. J. Olling
  CAE/CAD/CAM Research and Development
  Executive Engineer
  Chrysler Corporation
  12000 Chrysler Drive
  Highland Park, MI 48288-1118
  Tel 313-956-1803
  Fax 313-252-7152

- Professor Toshio Sata
  Vice President Institute of

Physical Chemistry Research
Hirosawa 2-1, Wako,
Saitama 351-01, JAPAN
Tel 81-484-65-6641
Fax 81-484-67-5942

- Professor N. P. Suh
Massachusetts Institute of Technology
Chairman, Department of Mechanical Engineering
77 Massachusetts Avenue, Room 3-173
Cambridge, MA 02139
Tel 617-253-2225
Fax 617-258-6156

- Professor V. A. Tipnis
President, Synergy International Inc.
285 Heards Ferry Road
Atlanta, GA 30328
Tel 404-851-0134
Fax 404-851-0134

- Professor Michael J. Wozny
Director, Rensselaer Design Research Center
Rensselaer Polytechnic Institute
Troy, NY 12180-3590
Tel 518-276-6751
Fax 518-276-2702

- Professor Hiroyuki Yoshikawa
Department of Precision Machinery Engineering
Vice President, The University of Tokyo
Hongo 7-3-1, Bunkyo-ku, Tokyo 113, JAPAN
Tel 81-3-3812-2111, ex. 6446
Fax 81-3-3812-8849

The organizers shared the opinion that it was necessary for a selective group of scientists and engineers from different countries to meet once a year in an open forum to intensively discuss the current practices, basic definitions and technical challenges, available technologies and computer tools. The first workshop, cosponsored by CIRP and IFIP (International Federation of Information Processing), was held in Japan in conjunction with the IFIP WG5.3 Conference (PROLAMAT '92) hosted by the University of Tokyo. The follow-up workshops will be held annually in either the United States or Europe.

[Author's comment. The workshop meeting room was overfilled beyond capacity by the attendees. Consequently, F. Kimura, who made many of the local arrangements, was forced to place some restrictions on those who wanted to participate. The result was that far fewer Japanese than I had expected actually attended. In many ways this was a Western meeting held in Japan. I am sure that the organizers will try to accommodate a sufficient number of interested scientists at subsequent workshops.]

WORKSHOP SUMMARY

The workshop participants began exchanging their ideas and views on the subject about one month before the meeting took place. Short position papers were submitted by participants, which stated their specific interests and concerns within the subject area. These papers were sent to all the invited participants before they departed for the meeting.

The two-day workshop was planned with minimal time devoted to formal presentations, thus allowing ample opportunities for discussions and debates. Four two-hour sessions were scheduled for each day. Only at the first session on the first day short presentations were made by four selected industrial participants. The speakers were selected from four different industries: computer, aerospace, automotive, and electronic in the United States of America and Japan; they specifically had been asked to speak about the impact and challenges of concurrent engineering in their respective industries. The purpose of these presentations was to develop a common background in the industrial needs and perspectives of the technology to stimulate and better focus our workshop discussions.

The presentations were 20 minutes long and were given by:

1. Dr. Frank Lynch of Digital Equipment Corporation, U.S.A.
2. Mr. Roy March of The Boeing Company, U.S.A.
3. Dr. Gus Olling of The Chrysler Corporation, U.S.A.
4. Mr. Kimio Inagaki of NEC Corporation, Japan

Dr. Lynch began his presentation by showing the role of corporate knowledge, both managerial and technical, in supporting the world-class product development practice in the computer industry. He

emphasized the importance of viewing knowledge as an asset in a corporation and suggested several different ways to manage this critical asset in a concurrent engineering environment. He explained some technical details of Digital's initiatives in developing an intelligent computer system that can help to manage the knowledge asset. He concluded the presentation by pointing out some critical issues and challenges that both managers and engineers must face in developing and using concurrent engineering technology in industrial practice.

The presentation by Mr. March focused on the special characters of the aerospace industry and how/where concurrent engineering can play an important role in meeting new challenges of the industry caused by changes in political forces around the world. He used the U.S. Department of Defense and the Boeing Company as an example to illustrate the requirement for a new kind of product development that challenges the company's ability to shorten the product-development time in building new military aircraft for the post cold-war era. Instead of the old-fashioned way of "order-then-develop-then-build", the new requirement will be "develop-then-order-then-build". He indicated many challenges, including vendor-supplier relations, in product development practice to meet these new requirements.

The challenges for the development of new products the strategies and their implementation plans in the Chrysler Corporation were outlined by Dr. Olling in his presentation. As an automotive company that must produce complex products of high quality and large volume in a very competitive and dynamic world market, concurrent engineering brings different meaning and challenges than those found in other types of industries. He explained how Chrysler showed initiative by bringing all business, engineering data, and tools into one integrated computer environment, and thus support concurrent engineering by shortening the product development lead time and improving the product quality.

Instead of focusing on specific company strategies, Mr. Inagaki presented a recent case of product development at NEC; the company needed to develop a new laptop computer within 90 days to meet the hazard of loosing market shares due to the introduction of a new laptop by the competitor. In contrast to other presentations that stressed the importance of new technologies, Mr. Inagaki described a very human-oriented and experience-centered approach to concurrent engineering. He explained how NEC quickly drew management and engineering expertise from other computer development projects in the company to organize a "tiger-team" with full authority over all aspects of the product development project. An innovative "backward scheduling" technique was used, that was strictly exercised to insure that the product would meet the 90-day target. Otherwise, the market share would be lost and a major change in marketing strategy would be required. This case study clearly pointed out that the success of the project team (i.e., they developed a new laptop computer from scratch within 90 days) was mainly due to

(1) the high urgency of the target,
(2) the highly motivated group with clear incentives,
(3) a strong experience base from related products,
(4) a highly cooperative team with full authority over its decisions, and
(5) a strictly enforced backward scheduling approach.

Mr. Inagaki's presentation stimulated many discussions among workshop participants on those more human-related issues of concurrent engineering such as management, experience, incentive, and authorization. [Author's comment. Inagaki's paper was greeted with astonishment from the Western participants, not only because of what NEC accomplished, but also by their methods. The entire team moved into a company complex where they lived for the 90 day duration of the project.]

The second morning session was organized to be a group brain-storming session where participants were asked to suggest critical issues that needed to be further discussed in the workshop. Based on the input from participants, two subgroups were formed to focus on

(a) infra-structural requirements, and
(b) enabling technologies of concurrent engineering.

Subgroup (a) was to identify those high-level intrastructural issues critical to the success of concurrent engineering, and to transform (i.e., map) these issues into a set of technological requirements. Subgroup (b) was to focus on defining a set of enabling technologies that could address those intrastructural and technological requirements identified by subgroup (a). Workshop participants

were asked to join one of the subgroups based on their interest and expertise. The afternoon sessions of the first day were devoted to subgroup discussions on these two subjects. During the first session on the second day, each subgroup reported back to the whole workshop about the progress and status of their discussions in order to better coordinate the continuing discussions. The afternoon was reserved for the final subgroup reports and synthesis of the workshop results (see the next section on Workshop Results). The last hour of the workshop was spent on collecting comments and feedback from participants about the workshop's technical theme and discussion format.

All participants felt the workshop was successful with respect to the goals that were set forth for it, and expressed high interest in continuing participation of such discussions in the future. They felt that the flexible and open format was effective and allowed to cover a wide range of issues. However, it was felt that the two-day workshop was perhaps too short to engage in elaborate discussions and debates of those identified issues. It was suggested that possibly a longer workshop and/or more thorough idea-exchange before the workshop were to be held in the future. Participants also liked the interdisciplinary nature of the group, and suggested ways to involve more industrial and international attendees in the future. They all expressed a strong interest to be continuously involved with this international group to advance the research, development, and application of the concurrent engineering approach in the product realization practice.

Finally, the workshop organizing committee reported on follow-up actions to this workshop. The workshop results would be written by the committee and sent to all participants for review. The approved report would be submitted to the sponsoring organizations (e.g., CIRP, IFIP, and ONR/USA) for circulation. Formal publication of these results in international journals would be pursued. Continuing communication among workshop participants would be organized and encouraged. Planning of future workshops (in different parts of the world) will also take place.

WORKSHOP RESULTS

(This report on Workshop Results was coauthored by F. Kimura, T. Kjellberg, F. Krause, S. Lu, and Mike Wozny.)

Introduction

The goal of a concurrent engineering system for product realization is to produce products that meet given cost, function, and quality requirements as rapidly as possible (lead time). The workshop attendees realized that concurrent engineering is a multiperspective issue that involves complex interplay among cultural, organizational, human, and technological aspects. Cultural, organizational, and human solutions needed for concurrent engineering require new technological support; at the same time, new technologies will not be successful without serious consideration given to their implications on cultures, organizations, and humans.

To facilitate and focus our discussions, two subgroups, one concentrating on those infrastructural (cultural, organizational, and human) issues of concurrent engineering and the other emphasizing those enabling technologies in response to infrastructural requirements, were organized in the workshop. This report summarizes and integrates discussion results from these two subgroups. We expect that these issues will be developed further in follow-on workshops.

The four major sections of this report cover key questions extensively discussed in our workshop:

(1) What are the key infrastructural requirements for the concurrent engineering approach to be successful in industries?

(2) What are the new technological needs that can be derived from the above infrastructural requirements?

(3) What are the necessary attributes of enabling technologies that meet the above technological needs?

(4) What are the critical enabling technologies that are needed by the implementation of concurrent engineering in industrial practice?

(1) InfraStructural Requirements of Concurrent Engineering:

(a) **Management of Change.** The success of future product realization systems will depend on the management's ability to handle change. Change,

at all levels, is now a way of life, and it must be carefully managed, whether it occurs at high strategic levels or low process characteristic levels.

There is no unified approach to understanding and modeling change in its various contexts. One can start at the strategic level where overall configuration is important. The next level involves organizational change, which includes the evolution and structure of teams. The more technical aspects involve product and process change characteristics such as tractability, measurability, repeatability and configurability. Culture also is an important, but poorly understood, element in managing change.

(b) **Availability of Information**. Concurrent engineering implies the sharing of information. Team is one means of sharing. However, existing technical approaches for sharing information are very primitive. They are governed by the state of computer communications and database technology not the state of concurrent engineering principles.

No theories or models exist to provide a foundation for information sharing, however, concepts such as cooperative problem solving show promise. Functions that enhance collaborative participation involve critique of designs, planning and execution of design changes, recording of design rationale, and maintenance of agendas, unfinished business or division of responsibilities. Why does the performance of a team that works effectively face-to-face in a conference room degrade significantly when its members must communicate via computers located in separate rooms? What is lost? What does it take, technologically, to make this virtually colocated team effective again; in fact superior?

(c) **Deep Common Understanding**. Making information available does not solve the problem unless one can act on it. Thus, information must be timely and meaningful. Information is meaningful when there is a common framework for understanding.

There are no theories, today, that provide useful models for accommodating, for example, different points of view, different disciplines, and various contexts in a product realization system. Although management is perhaps correct in implying that effective cross-functional teaming is primarily a management and not a technical problem today; the basic issue is that teaming or common understanding is not well understood. Which are the essential team qualities that enable a group of experts, with different backgrounds personalities and goals, to develop and produce a new product in the shortest possible time? If we understand these qualities, then computer tools can be developed to support teaming in a meaningful way, making the product realization system significantly more efficient and cost-effective.

Emerging concepts such as convergence and collaborative thinking, where each individual of a group builds up an understanding of a specialized knowledge different from all other group members in such a way that his/her expanded knowledge allows him/her to completely understand the needs and goals of all the other members, show promise. This new collective mindset allows all team members to grasp the cost of each other's activities, providing insights that result in a much deeper level of cooperative work.

Another key aspect of deep understanding is informal human networking, where workers have such a high level of confidence in each other that they can communicate highly reliable planning information well in advance of normal schedules. Again, no models exist for such networking.

(d) **Risk and Uncertainty**. A successful and rapid product development system, by its very definition, requires design decisions (for product or process) to be made very early in the cycle, when only incomplete information is available. Extensive experience and highly skilled judgment are required to make such decisions today, because current models for representing such incomplete information and assessing its risk are inadequate. Various concepts such as interval analysis, impact and risk assessment, and neural representations require further research.

(e) **Availability of Competent Workforce**. Sophisticated product realization systems require a sophisticated workforce. Shorter and shorter cycle times will force workers to learn new technologies, procedures, and skills more quickly. This short ramp-up time for people will change the way workers are selected, educated, trained, and rewarded. For example, instead of paying workers for the specific task they are performing, we can pay them for their skill level, regardless of current task, thus providing incentive to workers to continue to develop new skills. The more skill an individual has, the more adaptable he or she is to meet future unexpected needs, assuming the skills are in areas of future importance. Innovative education, training,

measurement, and reward theories and techniques are essential for successful future product realization systems.

(f) **Integration**. Concurrent engineering deals with creating an infrastructure that makes the enterprise more responsive. A responsive company must get the product right the first time. Today, the shorter lives of products simply do not leave time to correct design errors, nor to redesign products for lower cost or higher quality. Most of the profits from a successful product are realized early after its introduction.

A responsive enterprise requires global or integrated thinking. When one thinks globally, former CAD measures of productivity, such as "engineering drawing through-put" (drawings per unit time) are simply inadequate for the big picture, and they must be replaced by measures such as "number of engineering changes", or "time for ramp-up to volume production". There is no adequate modeling methodology that allows one to evaluate trade-offs in such global measures.

(g) **Standards**. Since much of the data dealing with product realization are technical in nature, the ability to effectively use cross-functional teams on a regular and extensive basis across an enterprise will be hindered until the data exchange problem is solved, i.e., until all users can communicate "transparently" across technologies and methodologies. Today, most CAD tools run separately; the models and representations are incompatible, and the user interfaces and databases are inconsistent.

Although there are many technical and bureaucratic problems associated with any evolving standard, the rapid development of the proposed ISO STEP standard is essential, if concurrent engineering is to achieve its potential in rapid product realization.

(2) Technological Requirements for Concurrent Engineering:

Given the above infrastructural requirements for a concurrent engineering system for product realization, this section describes the resulting technological requirements.

(a) **Information Architecture**. The computer-based information architecture must have the following attributes: It must accommodate a distributed computing environment, with the appropriate levels of security, based on open networking architecture to allow teams to work transparently, i.e., unhindered by the low-level computer workings. The workstations should have a common interface structure so that users can move from one computer application tool to another with minimal learning, i.e., allowing the user to concentrate on the tool and not the interface. The architecture should allow all the tools to be integrated in a way that minimal effort is required to move from one tool to the next. This also implies that the appropriate supervision and release mechanisms are in place, which tracks the progress of the design.

(c) **Decision Architecture**. This topic involves the overall strategy of how teams or groups of teams interact and make decisions when designing a product, and how the evolving design information is managed. One can envision a suite of utilities to enhance collaboration, such as a cooperating multiple agent inferencing network, based on agents representing functional islands of expertise. These agents cooperate with each other in a client-subcontractor mode, interacting on a demand basis requesting/providing services, with no predetermined flow of information and no dominant players. Each agent performs its function and informs associated agents of its solution. The associated agents check for constraint violations.

Such systems are useful for collaborative participation of teams in critiquing designs, planning and executing design changes, recording design rationale, maintaining agendas of unfinished business such as evaluations of designs, suggestions about goals and constraints of design changes, effects of proposed changes on other aspects of the design, changes under consideration or implementation, and the divisions of responsibility.

One can extend the above concept of intelligent agents to include brokering agents that have knowledge about specific services on the network and negotiate for services needed to complete a given task.

(c) **Management of Projects**. Key issues that must be considered in this area are: multiproject planning and control, project breakdown structure, scheduling, cost estimating, performance measurement, progress reporting, corrective actions, organization, and finally resource allocation.

(d). **Measurements**. Measurement techniques are needed at all levels, from the strategic enterprise level down to the real-time human team worker on the factory floor. Measurements involving the effectiveness of teaming concepts, as well as cross-functional departmental interaction (e.g.,

number of engineering change orders) are especially needed for concurrent engineering.

(e) **Modeling methodologies.** Five major classes of modeling methodologies are needed. This first involves information methodologies such as EXPRESS, where the information model can be implemented directly into a database (or object base) schema. The next class involves modeling of physical processes, including simulation as well as models useful in the manufacturability evaluation of in-progress designs. The third class involves methodologies for setting strategic and business goals, which will model enterprise-wide characteristics. The fourth class involves methodologies to model organizational structures and to determine what type of organization best fits the desired responsiveness or other goals. The final need is a methodology to model human behavior, since most effective manufacturing environments involve a carefully orchestrated interplay between humans and machines.

(f) **Migration Strategies.** The long term success of a concurrent engineering based product realization system is its ability to evolve to new hardware and software platforms, new tools and new networks. Most companies have large investments in computer systems, databases, and trained personnel that cannot be cost-effectively changed every time new enhancements appear. Consequently, techniques are needed for migrating existing environments to new enhancements. Utilities are needed that encapsulate existing tools so that they can be embedded into new environments with minimal alteration. Utilities that allow distributed environments to be easily reconfigured, including intelligent routing of existing software tools, are also needed.

(3) Attributes of Tasks/Functions for Concurrent Engineering Enabling Technologies:

In the following discussions, the term "technology" is used to describe both "tasks" or "functions" to be performed in a concurrent engineering environment, and "systems" or "modules" which are able to carry out those tasks and functions. A list of required attributes for those tasks and functions that concurrent engineering enabling technologies must meet is presented first. Then, a list of systems and modules of concurrent engineering enabling technologies is included.

To describe processes that run under the goal of concurrency for product realization, it is helpful to define attributes of needed tasks and functions. These attributes are collected to characterize the needed enabling technologies. The following nonexclusive list of attributes are presented without an order of importance: incomplete/uncertain, heterogeneous, interval, parallel, open, time-based, and shared. The single attributes can be interpreted as follows:

(a) **Incomplete/Uncertain.** With this attribute, it is indicated that processes in concurrent engineering have to deal with incomplete and uncertain information. Although current engineering systems must also handle incomplete and uncertain cases, concurrent engineering adds more serious demands on these situations. Early communication between downstream and upstream information is very important to concurrent engineering. Information, at early stages, often lacks details and complete specifications, and many different types of information must be communicated in parallel. Their communication mechanism and representation will be very different from that of current engineering. The ability to handle incomplete and uncertain information is a big difference in concept to sequential processes. It is advisable to look to various knowledge processing tools for its realization.

(b) **Heterogeneous.** The influences on decisions for product realization are manifold. Information can differ in content, representation, relation, and structure. It indicates also that decisions for such complex processes as product realization need knowledge from different related sources and domains. In a concurrent engineering environment, information in both data and knowledge forms, with different levels of abstraction, must be handled effectively to support communication and coordination. Such an heterogeneous information base is difficult to evaluate, interpret, and integrate in the right way and in conjunction with other information.

(c) **Interval.** This attribute has two meanings. One is the incremental availability of information, whether it is complete or incomplete. Unlike traditional single value systems, intervals do not force engineers to make unnecessary commitments to value specifications prematurely. They leave room (degrees of freedom) for others to fill in, thus avoiding many costly iterations at later stages. Such a "least commitment" approach to problem solving is a very critical and desirable characteristic of concurrent engineering. The second meaning of interval reflects time dependencies, indicating whether synchronization happens or not, and helping to improve coordination among engineering teams. It

also implies that the product realization process does not have to be a fully continuous one in practice.

(d) **Parallel.** This is a time characteristic of concurrent engineering. It describes a time overlap of one or more tasks. Although not all engineering tasks can be made parallel, the demand of shortening times for product realization makes parallel processes necessary in concurrent engineering. These processes can be performed locally or distributed. Keeping track of these kinds of processes demands new project structures and new project management methodologies. The term *parallel* also has a second meaning in concurrent engineering in that it indicates that the multiple competing perspectives of product life-cycle concerns must be considered in parallel rather than incorporated sequentially as with the case of traditional approaches.

(e) **Time-Based.** This attribute makes visible the demand of shortening product realization times. Tasks have to be shortened, but there are also dependencies to other tasks that run in parallel. Keeping track of those complex dependencies that vary with time, is a very critical task in concurrent engineering. In fact, most decisions in a concurrent engineering environment are intrinsically time-based. The questions of scheduling, backward scheduling, and project management have to be solved. In this context especially synchronization efforts between different project teams have to be made.

(f) **Open.** This is an attribute that describes architectures of the concurrent engineering environment. The architectures needed for concurrent engineering have to be open in the following sense. It is necessary to have the ability to include additional functionalities. This must be possible under the time constraint of parallelism. It has to include local and distributed activity. It has to be able to work with heterogeneous knowledge and information systems. It has to be able to include existing system modules as well as future ones. The demand for interfaces with other engineering systems is also high. Standards for data formats, procedural interfaces and networks are imperative.

(g) **Shared.** Goals, tasks, knowledge, data, must all be shared to achieve the goal of concurrent engineering. Here, it is necessary to describe shared resources as knowledge bases, information bases, networks and the distribution of work. It can include distributed work and has a strong impact on teaming (both real and virtual) by advanced information technology.

(4). Concurrent Engineering Enabling Technologies:

The concurrent engineering enabling technologies are put together under the organization of an architecture. It consists of the human as the center that has access to a Decision Support System (DSS), a Virtual Teaming Support System (VTSS), a Concurrent Product Life Cycle Modeling System (CLC-M), and a Time Responsive Intelligent Information System (TIIS). All these components are to be organized with respect to the infrastructural requirements identified by subgroup (a). The human is centered in this architecture, for the fact that it is seen as the overall measure and driving force as well as the controller of the functions that are performed. The emphasis of this human-centered architecture is seen as a new feature compared with conventional systems for product development support.

(a) **Decision Support System (DSS).** The DSS allows engineers to effectively use information for or from the team and individuals, thus making decisions more profound. As in the product life cycle, it is very difficult to handle and evaluate all available facts. When these facts are controversial, the DSS is seen as a tool for providing sound proposals that can be based on multicriteria evaluations, on simulation, or on feedback. The DSS also has to support decisions about the product development process, keeping track of decision rationale and histories. In this sense it also has to contain synchronization and project management capabilities. It seems to be useful to have additional capacity for project management available. The reason for that is the complexity of parallel work, which is especially difficult to manage under flexible degrees of parallelism. As decisions have to reflect the cooperation with suppliers and customers, they have to get access to the DSS capabilities.

(b) **Virtual Teaming Support (VTSS).** Since one human cannot provide all the knowledge and skills needed in the processes of product development, it is essential to be able to work in teams. For group work there is a need to have personal contact or at least to have a virtual colocation. This is the root for demanding a Virtual Teaming Support System (VTSS). The features needed are for messages, and for human interaction by means of voice, text, and graphics. The purpose of it is for sharing knowledge, for analyzing problems, for cooperative decision making and problem solving. The requirements for

virtual teaming technologies in concurrent engineering go far beyond the capabilities of those electronic meeting systems currently available. They must support team interactions that could be distributed or centralized, synchronous or asynchronous, technical or administrative, involving both people and machines.

(c) **Concurrent Product Life Cycle Modeling System (CLCM)**. Geometric modelers and product modelers will still be a basis of future modeling systems in concurrent engineering. But the demands go beyond the available possibilities. For concurrent engineering it is necessary to have modelers available that can meet the modeling requirements at all phases of a product life. The different influences of the product, the production process, the usage and recycling have to be taken into account. Also, the market, the customer, maintenance and repair have to be modeled. These modelers will be product dependent; therefore, demands arise for open architectures. As these modeling functions will be performed in a team, they have to be sharable as well.

(d) **Time Responsive Intelligent Information System (TIIS)**. To support the systems already described, it is necessary to have a storage and a *retrieval of information available* that can be used by different users simultaneously, under time constraints of parallel work, and in synchronization. Another need is to handle information in an intelligent way. This feature can cover several demands such as having the needed information available at the right place in the right time, distributing information to the right members of the team, gathering information in such a way that it is of further use for product life cycle modelling. It has to process information and knowledge not only for storing, but also for output and understanding. The ability to present information for multiple perspectives and levels of abstraction is very critical here. The system has to document for long term, but it also has to be fast in response even for very old information. It has to work not only with company owned sources, but also with suppliers.

FACTS ABOUT CIRP

CIRP: Its AIMS, Structure and Activities

The early days

In the late 1940s it was becoming increasingly clear that the development of new production techniques was being hampered by the lack of appropriate analysis methods. There was evidently an urgent need for fundamental research to be undertaken in this area. It was realized that, in view of the importance and scale of the problems to be tackled, only international cooperative action would be effective. A meeting was held to discuss these problems, which was attended by Messrs E. Bickel (Switzerland), D.F. Galloway (UK), P. Nicolau (France) and O. Peters (Belgium). It was decided that efforts should be made to bring together research workers studying the application of scientific methods to production technology. This initiative led to the foundation of the International Institution for Production Engineering Research (CIRP) in 1951.

Present day activities

Today, CIRP is increasingly turning its attention to the use of computerized methods for manufacturing control. In particular, automation, robotics interfacing, and the computer integrated factory of the future are all subjects that are receiving detailed consideration. Much of CIRP's work is now concerned with applying a systems approach to manufacturing, with the communication requirements of the CIM environment and with the role of people in future manufacturing processes.

Aims

CIRP's principal aims are:

- to promote international collaborative research into manufacturing processing methods, including the enhancement of production efficiency and quality of work,
- to establish regular contacts between research workers and hence provide a forum to stimulate information exchange,
- to convene conferences to discuss the results of promising research and to ensure their publication in an industrially useful form.

CIRP's activities are concerned with promoting the highest levels of scientific research, and as such its policies are strictly noncommercial. CIRP members are all internationally recognized scientists and engineers dedicated to common goals. The organization is fully independent and not restricted to national interests.

The membership is divided into three categories:

- Active members — generally directors or former directors of major production engineering laboratories;
- Corresponding Members — research workers with recognized credentials who have the potential to become active CIRP contributors and collaborators;
- Associate Members — companies or research institutions that support the aims of CIRP and that maintain an interest in the organization's activities.

Organization

At present, CIRP has about 250 active and corresponding members representing some 36 different countries. All the members have been co-opted into the organization after making significant contributions to production engineering research. The unique contribution that CIRP makes to manufacturing research is acknowledged by many of the world' s leading companies and research institutes, which provide active support through the associate membership scheme. CIRP also maintains close contact with international organizations such as ISO, UATI (Union of International Technical Associations), UNESCO and UNO. The technical activities, conferences and publications of CIRP are just one side of the multifaceted organization. There is, of course, a human side too.

Relationships built up over the years ensure that CIRP is not only known for its scientific standards but also for its friendliness and collegiality. All this and more make CIRP a truly unique organization—a world leader in production engineering research.

Scientific and Technical Committees

The Scientific and Technical Committees (STCS) ate the groups responsible for coordinating the collaborative research projects run by CIRP. The knowledge generated in each field of activity is distributed by publications and conferences to the manufacturing community at large. The main activities of the STCS are:

- collecting and analyzing bibliographies to document the state-of-the-art in particular areas of manufacturing,
- publishing synthesis reports on important technical problems,
- organizing seminars and meetings on specialist topics,
- preparing internationally accepted terminology to aid understanding and promote more precise scientific definitions,
- contributing to the work of the International Standardization Organization (ISO),
- surveying the state of the art of research being carried out in different laboratories in the world,
- studying and promoting the development of important new techniques and technologies,
- organizing cooperative research projects, comparative testing, and standardization of methods.

At present, ten STCS are in existence:

A — Assembly
C — Cutting
DN — Design
E — Physical
F — Forming
G — Abrasive Processes
M — Machine Tools
O — Optimization
Q — Dimensional Metrology in Quality Assurance
S — Surfaces

To support these activities an 11th STC (D) had been formed with the special responsibility for the publication of the CIRP dictionaries on production engineering. The dictionaries include the terminology and definitions of manufacturing parameters formulated by the individual STCS above. The specific fields of interest covered by the ten major STCS are outlined below.

Assembly (A)

- Techniques, processes, and equipment for the assembly and handling of parts, including design for assembly and the application of industrial robots.

- Terminology and symbols used to describe assembly and handling operations.

Cutting (C)

- Processes and techniques used to shape components by material removal (turning, milling etc.), including the processes of chip formation, the physical laws governing the wear of cutting tools and the factors influencing surface finish.

Design (DN)

- Conceptual and innovative processes in engineering design.
- Design for economic manufacture, coordination with manufacturing.
- Computer—automated systems and the integration of technological and economic methods.
- Interfacing of CAD/CAM systems.
- Databases for CAD systems.

Physical and Chemical Machining (E)

- Research into material removal processes of a physical, physico-chemical or chemical nature, such as electro-discharging machining (EDM), electrochemical machining (ECM) and the use of high energy laser, electron and ion beams.

Forming (F)

- Processes in which components are shaped by plastic deformation, including pressure joining and separation techniques such as stamping, and shearing.
- Application of the theory of plasticity to industrial forming processes with reference to tribology and materials engineering aspects.

Abrasive Processes (G)

- Research into material removal processes using hard abrasive grains such as grinding and finishing. Attention is largely focused on the mechanics of grinding and the economics of abrasive processes.

Machines (M)

- Design, manufacture, and use of manufacturing equipment, including the study of performance related factors, such as static and dynamic behavior, efficiency, and resistance to wear.
- Control of production processes and the application of new materials.
- Automation, interfaces, and control systems.

Optimization (O)

- Techniques for economic, technical, and human optimization of overall manufacturing systems.
- Design for production, factory equipment selection, and lay-out, numerical and adaptive control, application of computers to manufacturing, information technology and human factors in production engineering.
- Advising the other STCS about the optimization of manufacturing systems.

Dimensional Metrology in Quality Assurance (Q)

- Development and application of measuring techniques to be used for quality control procedures, involving the measurement of size, shape, and positional relationships in manufactured components and assemblies.
- Nanotechnology processes and equipment.

Surfaces (S)

- Research of the geometrical, physical, and chemical properties of the workpiece surface in relation to the production process concerned. This has involved the preparation of a CIRP standard for measuring roughness parameters and collaborative projects on measuring surface hardness, residual stresses and crack detection on workpiece surfaces.

Human Aspects of Production Engineering

Process in production engineering depends mainly on the development and application of new scientific knowledge. However, to achieve progress,

the related human and sociological aspects also have to be taken into account. From its inception in 1951, CIRP has always striven to understand the interaction between manufacturing technology and the human dimension. The Round Table held every year during the General Assembly has frequently dealt with the environmental and human problems associated with manufacturing industry.

This has involved discussion of:

- The coordination of research among universities, government institutes, and industry;
- The economic, social, and environmental impact of the computer-controlled factory;
- Evaluation of the education and training given to manufacturing engineers.

In addition, the following special task forces have been instituted. Education and training that deal with the important and difficult problems of teaching the new technologies involved in computer-integrated manufacturing systems.

- Developing countries — the examination of how new technologies can be applied to less industrialized countries.
- Technology Assessment — Analyses of the human and social aspects associated with the introduction of new technology.

General Assembly

Each year, the General Assembly of CIRP is held in one of the home countries of the respective members. During the General Assembly, which lasts one week, papers are presented on a range of topics including keynote speeches on state-of-the-art that cover work done by CIRP members over the years. The collaborative research programs of the STCS and working groups are also discussed at this time. The meeting affords a unique opportunity for participants to update their knowledge of the developments taking place in manufacturing industry. The General Assembly is organized as follows.

Opening Conferences — National contributions organized by representatives of the host country, which deal with the prominent achievements of local industries, and the contributions made by key industrialists and academics.

Keynote papers — State-of-the-art papers, often written by joint authors, that summarize the technical and scientific aspects of particular areas of manufacturing. Moreover, the final results of collaborative research are generally presented in the form of keynote papers.

Technical papers — Some hundred and fifty technical papers are presented and discussed each year covering the latest research carried out by CIRP members.

Round Table — An open forum discussion on issues of general interest. Following an introduction by recognized experts, attempts are made to establish a consensus view on a particular subject. Wide-ranging, topical, and sometimes controversial issues are discussed at these sessions. Themes for the Round Table discussions are proposed by the STCS with the final selection being made by a committee of STC Presidents and Secretaries.

Scientific and Technical Committees — the STCS meet during the later part of the General Assembly to discuss the results of the collaborative research programs in detail.

Publications

CIRP Annuals — 700 pages in two annual volumes:

- volume I contains all the technical papers presented at the General Assembly (about 150);
- volume II contains synthesis reports such as keynote papers that survey the state-of-the-art of particular areas of manufacturing; technical reports that summarize the major results of collaborative research conducted in the STCS; text of the Round Table discussions; conferences of general interest that were held during the period of the General Assembly; progress reports of the STCS.

CIRP Dictionaries

The dictionaries are written by CIRP members, who are actively involved in research. They contain equivalent terms for the various production processes in English, German and French. A comprehensive list of the subjects covered in the dictionaries is available from the CIRP Secretariat.

Proceedings of CIRP seminars

- Annual Manufacturing Systems Seminar;
- Working Seminar on Computer-Aided Process Planning (1985);

- Working Seminars of the different STCS.

CIRP Technical Reports

- Unification recommendations;
- Register of laboratories.

Information:

For further information please contact:

Secretariat CIRP (opening hours 9.00-13.00)
10 Rue Mansart
75009 Paris, France
Tel: +33 1 45 26 21 802

INTERNATIONAL WORKSHOP ON INFORMATION AND IMAGE DISPLAY, OCTOBER 1992, HITACHI CITY, JAPAN

Key developments in flat panel technology were discussed at the International Workshop on Information and Image Displays (IWIID92), 8-9 Oct 1992, Hitachi City, Japan, and they are summarized and assessed here. Included is also a very brief summary of Japan Display '92. A summary of the 6/92 JTEC report on Display Technologies in Japan is also reported.

David K. Kahaner

October is a busy month for those people interested in Japanese electronics. The Japan Electronics Show draws hundreds of thousands of participants (13-17 October, Osaka), and it is the focus of activity. Associated with it are other meetings as well. One large technical meeting is Japan Display '92, JD'92, (12-14 October, Hiroshima) with more than one-thousand participants and over two-hundred technical papers; a brief discussion is given at the end of this report. As a satellite meeting associated with JD'92, a small invitational workshop, International Workshop on Information and Image Displays (IWIID92), 8-9 Oct 1992, was held near Hitachi City, approximately 90 min north of Tokyo on the Pacific coast of Japan. Various Hitachi laboratories are near there, including the Hitachi Research Laboratory, which was the workshop venue. Hitachi provided conference facilities in a special building suitable for such meetings, transportation, administrative and other support for the workshop. A display workshop at Hitachi is appropriate, as Hitachi has been involved in ongoing research at this laboratory on LCDs (liquid crystal displays) for more than twenty years. Participation by about 85 engineers and managers was evenly divided between Japanese and Westerners, with excellent representation from scientists from the major Japanese electronics corporations. IWIID92 differed from the much larger JD'92 by having a more limited scope, more retrospective and projective presentations, and of course a more interactive format that led to much more candid discussions. Most of the workshop participants were proceeding directly on to the larger meeting in Hiroshima. IWIID92 was sponsored by the Society for Information Display, Japan Chapter.

The formal objectives of the workshop were to provide a forum for discussion of

(1) present and future prospects of information displays and
(2) user needs and reliability of future display devices.

Although limited by the day and a half duration, the workshop achieved these objectives, and most participants left with a sense that they understood the key issues for the remainder of the decade.

Because display technology is a vast subject covered more fully at the larger JD'92, because there has been a comprehensive JTEC report on Flat Panel Displays issued recently (June 1992), and also because a series of symposia on displays will take place in late January 1993 at the San Jose Convention Center, San Jose, California, this report limits itself to describing the key ideas presented at IWIID'92 and makes no effort to survey the entire field or present background descriptions. The Executive Summary of the JTEC report is attached to the present report. Further, several IWIID'92 participants have promised to provide summaries of JD'92 and also an integrated discussion of the two

meetings. Thus the current report should be thought of as interim and we make no attempt here to be complete.

A dozen speakers and panelists made presentations; each was a recognized expert in research, engineering, or marketing areas of displays. In keeping with the informal nature of the workshop, there were no printed Proceedings, although some speakers did provide short abstracts that were distributed. I have identified the speakers by their organization, but because the discussions were informal, comments from industrial scientists need not represent plans or directions of their corporate employers. A list of titles of the presentations follows the text of this report. One speaker (Odawara, see below) sent me a copy of his slides; others on both sides of the Pacific were reluctant to distribute their presentation materials. Readers should contact the authors directly to determine if printed material is available.

In assessing the important developments, I would like to particularly thank

Dr. Lawrence E. Tannas, Jr, President
Tannas Electronics
1426 Dana Place
Orange California 92666
Tel: (714) 633-7874
Fax: (714) 633-4174

who not only explained many of the concepts to me, but also provided me with a written brief summarizing his impressions of the workshop. Dr. Tannas was the cochair of the aforementioned JTEC report.

The key issues discussed during this workshop are as follows.

The title of this workshop suggested that there is some difference between displays for information and for images, with the former usually referring to text. This may have been true in the past, but the participants generally rejected this distinction by commenting that new computer user interfaces are heavily dependent on image manipulation through graphical user interfaces and, multimedia applications.

Although tremendous progress has been achieved in active matrix, supertwist, and plasma technologies; a really excellent flat panel display that could be used as a replacement for a CRT (shadow mask color cathode-ray tube) is not here yet. The latter has had over forty years of continuous improvement starting with an excellent principle, and further improvements are still likely. The main problems for CRTs relate to mounting technology, such as weight and depth. All existing flat panels have limitations related to cost, resolution, speed, luminance, and viewing angle. Currently the goals of cheaper, better (larger, brighter, more colors, more appealing, etc.), and faster, seem to be at cross purposes. A representative of each of the various display technologies spoke enthusiastically about why his or hers was clearly the best for the future. Most manufacturers see that flat panel technology is strategic, and while production occurs in many countries, high value product production is almost entirely produced in Japan.

Liquid crystals have a regular molecular orientation, but because their intermolecular force is very weak (unlike solid crystals) the orientation can easily be changed by an electric or magnetic field. Because liquid crystals have strong optical anisotropy, a change in the molecular orientation results in changes in their optical characteristics, which vary widely depending on the composition of the liquid crystal, its surface orientation, and voltage applied. This is the fundamental property that underlies the development of flat panel displays. Odawara (Hitachi) presented estimates from Nomura Research Institute that the LC panel market could grow to US$5.5B by the year 2000, approximately 25% for TV applications, nearly as much for automotive, and the balance in other application areas.

(1) Active Matrix Liquid Crystal Display (AMLCD) market size — The primary market was assumed to be various forms of PC and pen-based computers, totaling one to three million units per year, but there are only a small percentage of these computers that presently use AMLCD. (The first Sony pen-based computer, the Palm Top appeared in 1990.) At least one participant has studied the investment in production capacity in Japan, and concluded that capacity would reach one million units per month by 1995. There was some disagreement about the accuracy of these estimates, but there seemed to be a general agreement that capacity would greatly exceed production, and the supply would similarly exceed the market potential. (Yamamoto (Toshiba) pointed out that there are already 200 suppliers of notebook computers including 50 Toshiba models that have sold more than three million units since 1986. The newest has a TFT color LCD display with 256 colors.) H. Morimoto (Sharp) suggested that new markets, such as automotive, games, and more video applications, would be

opening. Potentially the automotive market seems very large, and there are already many Japanese autos with flat panel displays in place. However, one Japanese scientist told me that the really large growth in that market would probably occur later in the decade, after 1995. At least five major Japanese manufacturers are currently ramping up volume production to capture market share. While low end displays are commodities, high performance displays are very expensive to develop. The result is that mainly the large companies are involved in the development and manufacturing of high performance flat panel displays. There are significant problems in the manufacturing of full color AMLCDs that no one has yet solved. The global economic slowdown has slowed PC sales worldwide, and sales are growing at about half the rate projected as recently as one year ago. At the same time, the manufacturing yield continues to improve and to edge beyond 50% for most manufacturers. Thus, there will likely be a very turbulent market for AMLCDs for the next several years.

(2) Plasma Display Panel displays for HDTV — The Plasma Display Panels (PDP) community hopes that PDP will meet the needs of HDTV direct-view displays (as distinguished from projection systems). Kurashige (NHK) strongly argued with pictures and graphs to support this position, and discussed a 40-inch full color plasma display. This was demonstrated in June 1992 at NHK's laboratory near Tokyo. It contained somewhat fewer than one million pixels (but scales to 2 million for a 55-inch diagonal version), weighs 8kg, has only 150W panel power consumption, and a brightness of more than 50cd/m^2. Shinoda (Fujitsu) stated that Fujitsu would show a 21-inch full color VGA AC plasma display with 0.66 pitch, 256 grey scale, and 200cd/-m^2 luminance at this year's Japan Electronics Show (this month). Most participants, including the speakers from Fujitsu and NHK, felt that the obvious niche for plasma displays was in large-area, low-resolution applications such as television, and even HDTV. However, L. Weber of Plasma Co. pointed out very credibly that the PDPs have fundamental materials limitations in luminance, luminous efficiency needed to be better than one lumen per watt, and lifetime. Until these problems are solved, PDP cannot be expected to be used for large (60-inch) HDTV color displays. There did not seem to be any argument to this point of view. In other discussions it was made clear that real progress in displays will probably come from large numbers of researchers making many improvements, and that plasma display research teams are outnumbered at least one hundred to one by AMLCD groups. Outside of the community of PDP researchers, there was a general sense that usage will decrease and would only remain strong within the industrial and commercial market where applications can capitalize on the ruggedness and long life of the displays.

(3) Size of AMLCD — Morimoto (Sharp) confirmed the announcement that Sharp would show a 17-inch AMLCD with 1280 × 1024 resolution also shown at the 1992 Japan Electronics Show. Last year, at the 1991 show, Matsushita exhibited a 15-inch display, the largest seen so far. However, Morimoto said that they would not be manufacturing AMLCDs much larger than 10-inches because of the stepper size limitations.

(4) Price of AMLCDs and standardization of sizes. — Several users repeated that the price of AMLCDs would come down and that there was a need to focus on standardizing sizes instead of on performance improvements. Several comments were made about $600 VGA displays by 1995, but I had no sense of whether there was agreement on this occurrence, although prices are clearly falling.

T. Credelle (Apple) felt that when AM color display prices fall below $1000, they will become seriously interesting for companies like his; however, power requirements were the main impediments to the widespread use of color displays. It was felt that monochrome high-performance computers for less than $1000 will put serious price pressure on color systems. Film-compensated supertwisted nematic (FSTN) LCDs in color are good enough for computers, but AMLCDs are still needed for video. (The main issue seems to be the response time and gray-scale or color requirements.) Avionics users want better viewing angle performance and pen--computer people want less parallax. W. Goede (Northrop) pointed out that most of his (avionics) customers have been specifying flat panel displays. But he felt that if one looked at the numbers, current needs could probably be met, today, by using CRTs. There was some discussion about this, but Goede held ground by pointing out that specifying flat panels in aircraft seemed natural to customers and it was impossible to convince them that perhaps the technology was not yet able to provide the required display performance, although flat panels were suitable for alphanumeric use. Goede felt that LCDs were currently in the most advanced state, LEDs (Light Emitting Diodes) were limited to

applications with small viewing angles and on small volume displays, ELDs (Electroluminescent Displays) will be limited to applications without severe ambient light conditions; although, use in industrial, medical, instrumentation, and communication is also growing because of their long life, ruggedness, and ability to work in wide temperature range. They seem to fit in high-value, high-performance displays and are especially well suited to touch panels. While conceptually appealing, problems of power and absence of backlighting remain to be solved. Finally, flat CRTs were interesting but far behind (developments in flat CRTs have not yet resulted in large units).

(5) Active Matrix Addressing announced last year by InFocus — Considerable excitement about the new addressing scheme was shown. However, it does not change any previous concept in matrix addressing of flat panel displays. (Addressing refers to the problem of getting a signal from the sides of a panel to a designated spot at the interior.) It was generally conceded that it does improve FSTN LCDs but could not make FSTN displays as good as AMLCDs. Further, it would impact the cost of the FSTN drivers and controller chips. Many participants felt that it will take further development and demonstrations to determine if the improvement will justify the extra cost.

(6) Philips Diode AMLCD — Philips showed a very good performing display in the lobby of the workshop site, and C.J. Gerritsma (Philips) said that it was made with only four photolithographic steps and two diodes per pixel, leading to higher yields and lower cost. They are expecting to simplify the manufacturing method even more. It was felt that if Philips is successful in refining their production methods, this will reduce the cost of AMLCDs but not in a significant way. Because of a simpler process, a direct cost improvement will show where the yield is improved.

(7) Polysilicon AMLCDs — Ohshima (Seiko Epson) summarized the current advantages and disadvantages of Poly-Si as follows.

+ High resolution displays possible
+ Device driver electronics can be integrated on the panel
- Production process is too hot, currently beyond 1000°C
- A low temperature production process (under 600°C) is still at the R&D stage

Both Chiang (Xerox) and Ohshima said that they are at least one to two years away from completing a low-temperature process suitable for production. This was seen as a significant revelation and certainly a blow to those advocating Poly-Si for AMLCDs. Nevertheless, there was significant interest in Poly-Si, which is seen as (potentially) being much better than amorphous silicon used currently. Chiang felt that the applications were first to high-resolution and small-size displays, with 10^{18} pixels possible on an 18-in display. (Another new technology that was mentioned several times at the workshop was Field Emitter Arrays. This was described repeatedly as exciting, but with many problems yet to be overcome. However, colleagues have told me that funding for Field Emitter research at Japanese companies seems to be on the verge of drying up.)

(8) Displays for HDTV — Several speakers described the projected cost of HDTV displays, only to conclude that they are still too expensive for consumption, while at least one speaker insisted that HDTV displays needed to be large to generate the necessary visual impact. In summary, the display device developers and manufacturers still do not have a suitable solution or candidate recommendation for the consumer-priced HDTV display. However, Maruyama of Hitachi claimed that 40-in HDTV based on TFT-LCDs would be available by 1995 with 500M dots. Kurashige (NHK) explained that a 55-inch muse home receiver was targeted within five years.

(9) FSTN — It was emphasized that, for portable PCs, FSTNs were good enough. Now price is more important than performance. The speed, viewing angle, brightness, and color are considered acceptable. There is no utilitarian need for AMLCDs in portable PCs and pen computers unless good video is required.

E. Maruyama remarked that a new and promising field of electronics is opening up with the development of TFT-LCD in large sizes using printing technology, which he felt would be suitable for displays larger than 15-in (below that, photo lithography was still thought to be better). Although there is excitement about the developments of Poly-Si he will continue to bet on amorphous silicon.

One of the more exciting presentations was from

Mr Kozo Odawara
Senior Chief Engineer

Electron Tube & Devices Division
Hitachi Ltd
New Marunouchi Bldg., 5-1
Marunouchi 1-chome
Chiyoda-ku, Tokyo 100 Japan
Tel: +81 3-3212-1111
Fax: +81 3-3212-3857

who discussed issues and possible solutions for future displays, based on his 35 years experience at Hitachi. He presented a series of detailed slides showing possible trends in markets, direct and indirect costs, and realization requirements for displays in the 21st century. Mr. Odawara graciously sent me copies of his slides. Although they are too detailed to include here, he points out that by the year 2000 he expects color CRT and LC displays to coexist, essentially sharing an approximately 5T Yen (over US$40B) per year market. (Equal sharing of the display market between CRT and LC by year 2000 was also predicted by the JTEC report.) Readers are urged to contact Odawara for further information.

Associated with the workshop was a very small exhibition. The Philips prototype was mentioned above. There was also a 9.4-in TFT-LCD from Hitachi with VGA (640 × 480) specifications, with .3mm pixel pitch, 512 colors, 50ms response time, and only 10mm thick. Nevertheless, two participants from IBM; W. Howard (who was one of the general cochairpersons of the workshop), and H.Funk (Email: FUNK@VNET.IBM.COM), claimed that IBM's new notebook, just released the week of this workshop, had an outstanding display. (I have not seen it yet.) Howard also commented that IBM had a panel-testing-unit installed within its production facilities (here in Japan) that tests a full panel in about 1 min.

Most participants felt that the discussions were more open and candid than usual, especially considering that this is a topic of much competition. Perhaps this resulted from the recognition that there are many unsolved and difficult problems.

ACADEMIC INTERNETWORKING IN JAPAN

Internetworking is somewhat new in Japan. It came to be known when JUNET started operation in 1984 by using dial-up lines and UUCP. Research people were hooked to e-mails and began subscribing to e-news. But it was after the entry of Japanese texts became easier when e-mails and e-news became really popular. The Japanization required the use of 2-byte codes (the so-called JIS 7-bit codes) and the modification of networking program (mainly on UNIX) to accommodate 2-byte codes. In the meantime, a serious internetworking began in 1987, when the JUNET was extended to WIDE, which employs leased-lines and TCP/IP protocols to interconnect LANs in many institutions. Today, besides JUNET and WIDE several major internets exit in Japan, such as BITNET, JAIN, TISN, SINET, HEPNET-J, TRAIN etc. and some have international links to the United States of America. But the transmission speed is limited from 64 to 192 Kbps because of high tariffs, lack of funding, and lack of coordination. In this paper, we discuss the background and history, current status of Japanese internets, and their applications. Finally, we will point out various problems facing our internets in Japan.

Haruhisa Ishida

BACKGROUND AND HISTORY

Internetworking is a relatively new concept in Japan, not well known until about the time when the WIDE project was started in 1987. The reasons of this rather late start-up of internetworking despite the widespread use ot computers in general seem to be the following.

1. Centralized computing has been dominant. A computer network meant mainframe-to-terminal connections or a network of mainframes as is the case of the interuniversity network called N1net. Japan has many large-scale online networks used by banks, security houses, and railway systems, but they are not what we call internets.

2. LAN has not been widely used. It has begun to be used only recently with now fashionable "downsizing" trend. Currently many universities are trying to install LANs based on Ethernets (10 Mbps) and FDDI (100 Mbps).

3. Each computer manufacturer has been using propriety network protocols represented by such names as SNA (IBM), FNA (Fujitsu), HNA (Hitachi) DINA (NEC) and DECnet (DEC), making internetworking difficult. The makers are only now starting to promote UNIX-based system as *open systems*.

4. The TCP/IP protocol has not been recognized as a standard protocol. The government and computer/communications industries have been trying to develop OSI protocol products. However OSI efforts have been very disappointing as in other countries and, with the proliferation of UNIX systems, TCP/IP is now regarded as the best protocol for internetworking under the influence of the United States of America.

5. Routers have not been readily available with support and training in the Japanese language. Routers developed by U.S. venture companies are used widely, and Japanese makers are not in the market yet. They are software-intensive equipment, and their design requires

detailed knowledge of a variety of protocols. This seems to be a difficulty for Japanese makers who want to get into this market.

6. Postal regulation and high cost of leased lines have not encouraged personal communication on networks.

7. It has been difficult to enter Japanese and Chinese texts into computers even if an e-mail facility existed. This language barrier has deterred us to use electronic mails because most of our users want to use our native tongue in communications with colleagues. People began to show interest in using e-mails only after 1987 when popular Japanese wordprocessing software such as Ichitaro (Version 3) appeared and made Japanese character entry easier.

8. Japan is a small country and most activities are concentrated in Tokyo. So face-to-face meetings are not difficult, thus requiring less need for e-mails.

9. Leased lines are very costly. NTT's (Japan's largest telephone company) big effort is to make ISDN a nationwide service while keeping leased lines relatively expensive. Thanks to this policy supported by the government, the ISDN service is available in most cities in Japan, but the cost to use leased lines has not come down much.

In this background, the first attempt to build a nationwide academic network was the N1 project started in 1974. It had an NSF like support from the Ministry of Education of Japan from 1973 to 1979. The participants were three universities (Tokyo, Kyoto, and Tohoku), a common carrier (NTT) and three computer makers (Hitachi, Fujitsu, and NEC). The resulting wide-area network called N1net links heterogeneous mainframe computers from three makers. The N1 protocol developed in the project was designed with the ARPANET protocol as a model. It had remote login (network TSS), RJE (Remote Job Entry) and limited file transfer (allows only fixed-length-records of 80 bytes) capabilities. This network was the very first WAN that employed the commercial packet-switching service called DDX (Digital Data Exchange) started by NTT in 1980.

The N1net did not have any mail/news exchange facilities because they were not allowed to have it under the communication regulations then in existence. Also we (the developers) were not aware of the significance of electronic mails, and entry of Japanese texts was difficult. No attempt was made to experiment the idea of personal communication by using the network. It was only a resource-sharing network. This was quite different from the ARPAnet where much of the traffic were e-mails as we learned later.

In retrospect, although the N1 protocol was a proprietary protocol of the 7 parties, the specification was public and it was (and still is) almost the only network protocol in widespread use for linking heterogeneous computers.

In 1984, when an e-mail/e-news exchange network called JUNET (Japanese University/UNIX NETwork) was initiated by a group of Keio University, TIT (Tokyo Institute of Technology) and the University of Tokyo researchers. The group leader was Dr. Jun Murai (then with TIT). We used telephone lines (at 9,600 bps) and the UUCP protocol to link UNIX computers at the three institutions.

The dialup JUNET was an instant success. The number of participating organizations increased rapidly soon afterwards. Not only universities but also industrial research laboratories joined. This combination of universities and industries was unusual in Japan where administrative barriers exist between the two. JUNET was possible because it did not rely on government funds, and it was operated completely on volunteer basis. Thus it is an unofficial network with no recognition from the government.

In the meantime, the BITNETJP, an extension of the BITNET to Japan, came into existence in 1986 with the support of IBM (during the first three years) when the Science University of Tokyo established a 56 Kbps link with the City University of New York. This was the very first international internetworking in Japan.

Then, in 1986, we started an international link from JUNET to the CSNET (Computer Science NETwork) in the United States of America by using a dialup packet switching circuit of KDD (Japan's overseas carrier) Venus-P (a packet switching service). In establishing the link from Tokyo University Computer Centre to BBN in the Boston area, it was fortunate for us to have had generous help from Prof. Larry Landweber of Wisconsin University, Prof. David Farber of Pennsylvania University, and Dr. Hideyuki Tokuda of CMU.

Dr. Jun Murai (then with University of Tokyo) initiated the WIDE (Widely Integrated and Distributed Environment) network project in 1987 as a joint project between universities and industrial research laboratories. The WIDE corresponds to a leased-line extension of JUNET and was the first true internet in Japan that employed 64 to 192 Kbps leased lines and the TCP/IP protocol. With substantial help from Prof. Torben Nielsen of the University of Hawaii, WIDE established a 64 Kbps international link to the United States Internet through Hawaii in 1989. Most of international mail traffic to and from Japan now goes through this

link. It is also possible to use telnet and ftp services internationally in much the same way as in the U.S. Internet. Thus Japan has become a member of the international internet community.

Some other academic networks besides N1net exist, BITNETJP and JUNET/WIDE in Japan. They include: SINET (Science Information NETwork) JAIN (Japan Academic Interuniversity Network) TISN (Todai International Science Network) HEPNET-J (High Energy Physics NETwork in Japan) TRAIN (Tokyo Regional Academic InterNet).

Figure 1 shows the main international links between Japan and the United States of America. Two links have been upgraded to 192 Kbps.

CURRENT STATUS OF MAJOR ACADEMIC NETWORKS

Japan has seven major academic internets with a total of 739 IP-style domains. Of these, the majority belongs to the UUCP-based JUNET.

1. WIDE — 58 domains

WIDE has a total of 6 NOCs (Network Operation Centers) in Tokyo, Fujisawa, Kyoto, Osaka, Fukuoka and Sendai (Fig. 2). The protocol used is TCP/IP and the line speed is 64-192 Kbps. TCP/IP over X.25 is used in some ISDN links with speeds of 64 or 128 Kbps. Organizations sponsoring the WIDE project have reached 58. Since WIDE is maintained in a research project, many research activities are being carried out by using WIDE as a testbed. They include ISDN applications, TCP/IP over X.25 and satellite (wireless and mobile) communications. More details will be reported by Jun Murai in another paper.

2. BITNETJP — 118 nodes in 82 institutions (domains)

The Science University of Tokyo has the Japan gateway to BITNET and acts as the hub of BITNETJP — Japanese portion of the BITNET. It had a 56 Kbps RSCS link to the City University of New York until the end of 1991 but changed it to a 56 Kbps TCP/IP link into JvNCnet at Princeton University in January 1992. BITNETJP is now a consortium called the Japan BITNET Association comprising of 82 institutions, most of which are private universities in Japan. The BITNETJP configuration is shown in Fig. 3. It is expected that most nodes will be reconfigured gradually to BITNET II (TCP/IP) from now on. Some confusion has appeared by using Japanese/Chinese characters on BITNETJP mails but its Kanji code was standardized to JIS 7-bit code just recently, in April 1992. The Japan BITNET Association has been active in promoting Asian connections and has links to Taiwan and Korea. BITNETJP has formed CAREN (Consortium of Asian Research and Educational Network) with Taiwan and Korea in July 1991. The CAREN has an agreement with CREN (Corporation for Research and Educational Networking) in the United States of America.

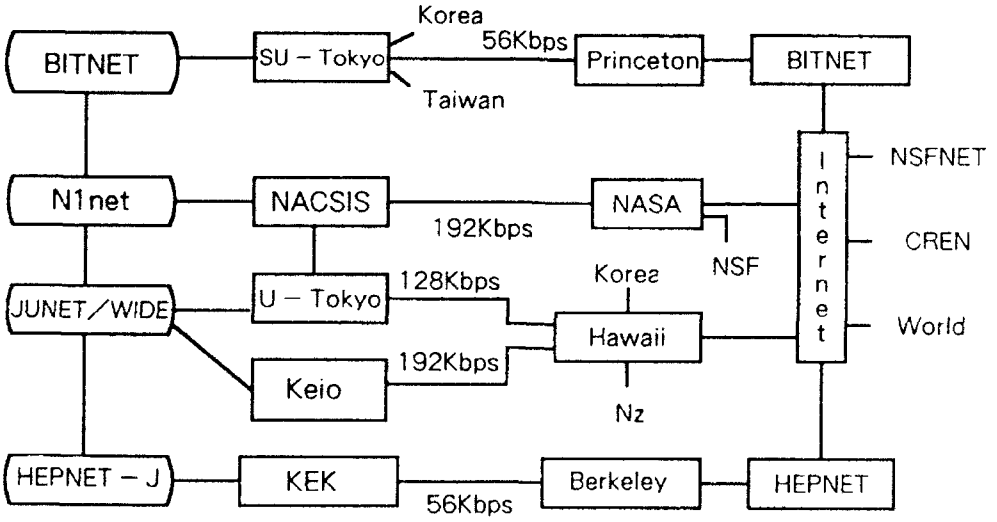

Fig. 1 — Main links between Japan and USA

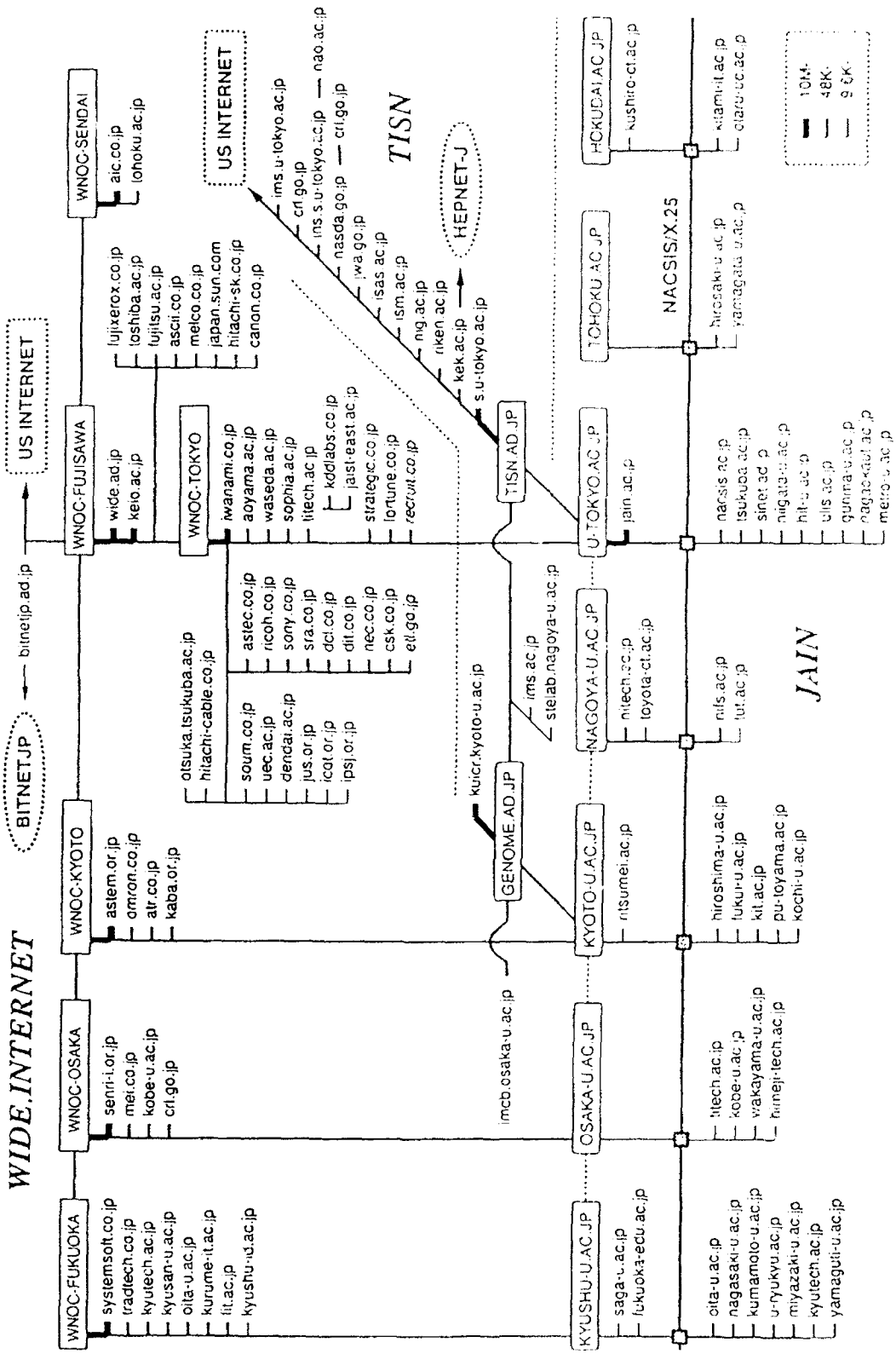

Fig. 2 — WIDE internet configuration

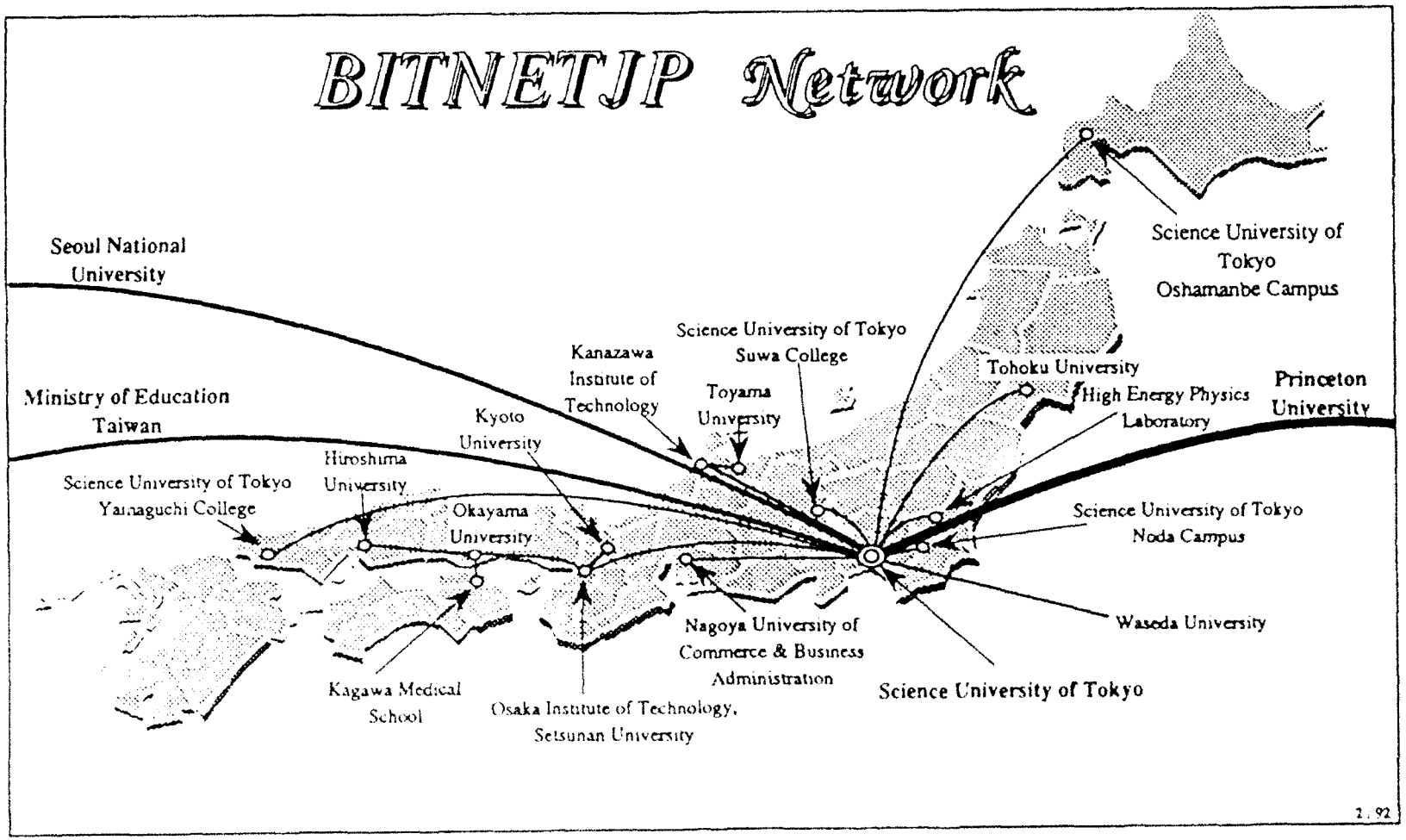

Fig. 3 — BITNET JP configuration

3. SINET — 9 domains

SINET is the backbone network maintained by NACSIS with nodes in eight universities, including Tsukuba University. NACSIS (National Center for Science Information Systems) is a national institute under the Ministry of Education. It is the center of the N1net (the mainframe network) and also the center of a library network linking major university libraries in Japan via N1 protocol with its own X.25 packet-switching lines leased from telephone companies. Since NACSIS is a national institute, it has held the stance to support OSI protocols and has actually led an effort to implement X.400 MHS mail systems on mainframes in the above universities.

In 1991 NACSIS started to support TCP/IP protocols. It has now a direct link (at 192 Kbps) to the FIX-West at NASA-Ames via a SPRINT international line. Thus it is in a position to compete and complement with the WIDE link for international services.

4. JAIN — 44 domains

JAIN is an experimental academic internet linking many universities mainly with X.25 packet switched lines provided by NACSIS. Although the protocol is TCP/IP, IP packets are carried by X.25 packets and hence the transmission is slow. It is expected that the practical part of JAIN will be absorbed by regional networks like TRAIN (described below) when experiments supported by the Ministry of Education are over. JAIN can be in a position to pursue gigabit network technology but no definite plan exists.

5. TISN — 17 domains

TISN is an internet linking two universities and 15 research laboratories in the field of sciences at 9.6 to 64 Kbps, as shown in Fig. 4. The protocol supported is DECnet and TCP/IP. The members include:

University of Tokyo,
  Faculty of Science
University of Tokyo,
  Institute for Nuclear
  Science
Kyoto University,
  Chemistry Laboratory
National Astronomical
  Observatory
National Institute of Genetics
Institute of Physical and
  Chemistry Research (Riken)
KEK (High Energy Physics
  Laboratory)
STE (Plasma Physics)
  Laboratory (in Nagoya)
Institute for Molecular Science
  Research (in Okazaki)
Cellular Engineering Laboratory
Communication Research
  Laboratory
NASDA (National Aero-Space
  Development Administration)
Institute for Space Science
  Research
Japan Atomic Energy Research Laboratory
Institute for Statistical and
  Mathematical Analysis
Japan Weather Association
Rikei Corporation

TISN was started in 1989, and now it has a 128 Kbps link to the U.S. Internet through the University of Hawaii. TISN reports that the traffic from Hawaii to Tokyo is about 1,700 Mbps per month, while the traffic from Tokyo to Hawaii is about 1,300 Mbytes per month.

6. HEPNET-J

This network centers around KEK (High Energy Physics Laboratory in Tsukuba) and has a link to U.S. HEPNET through Lawrence Berkeley Laboratory.

7. TRAIN and UTnet

TRAIN is the name of the first major regional internetwork being developed around the University of Tokyo Computer Centre. The Centre has installed three multiline routers contributed by Cisco, Proteon, and 3COM. Currently, it has only several links at 64 Kbps, but it is expected that the number will quickly increase.

The most important member of TRAIN is UTnet (University of Tokyo local-area network). UTnet constructed under a three-year project (1990-1992) by a grant from the Ministry of Education has three FDDI rings and a 400-Mbps multimedia ring connecting major buildings in the main campus. In each building, twisted-pair Ethernet wiring is used to link many PCs (Personal Computers) workstations, and mainframe computers. For other campuses, 768 Kbps and 1.5 Mbps leased lines are used as seen in Fig. 5. The 1.5 Mbps is the highest speed in Japanese internetworking at the moment.

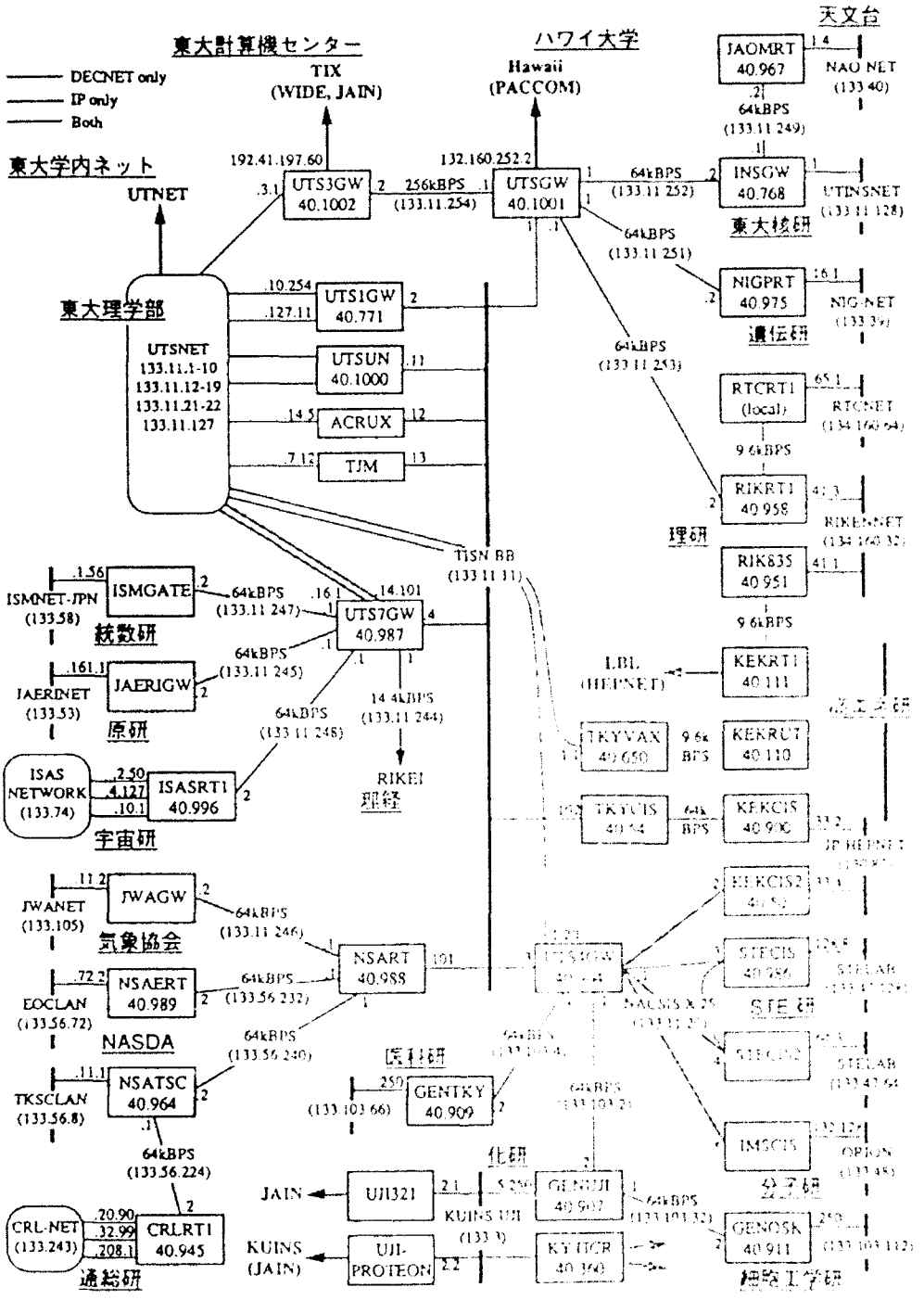

Fig. 4 — TISN configuration (as of January 1992)

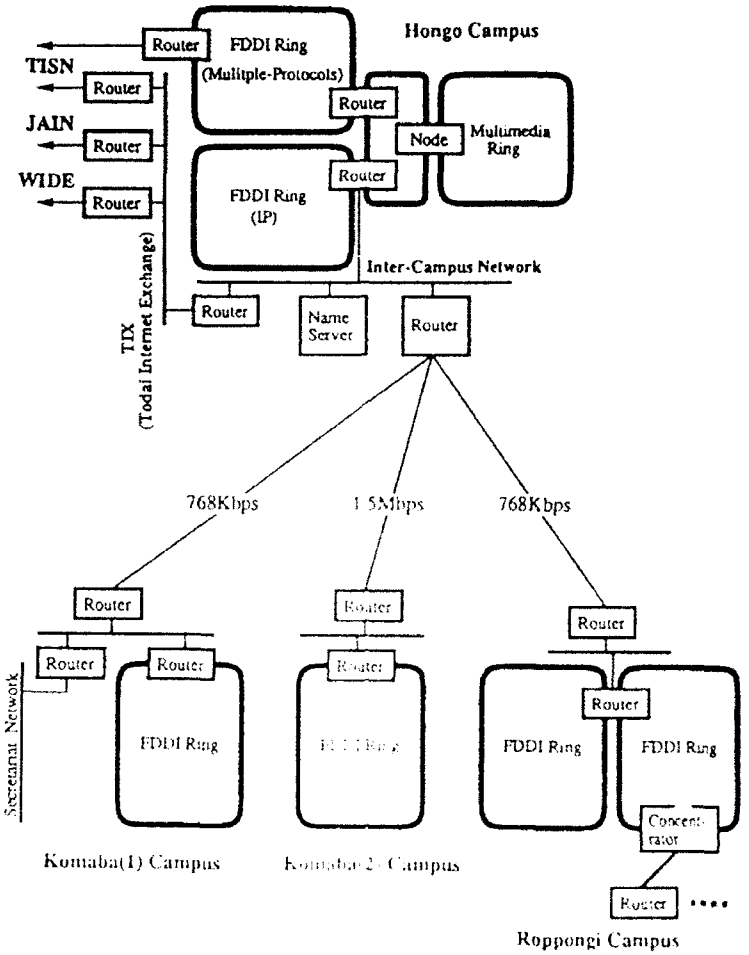

Fig. 5 — UTnet configuration

INTERNETWORK ADMINISTRATION AND MANAGEMENT

Several organizations are responsible for the administration and management of the entire Japanese internets.

1. JCRN (Japan Committee for Research Networks)

This is an academic network coordination committee organized in 1990 and chaired by Prof. Shoichi Noguchi of Tohoku University. The committee consists of the representatives of major academic networks and academic societies in Japan. We thought that the best place for combining both universities and industries is a meeting of academic societies. Coordination among WIDE, SINET, BITNETJP, and TISN is discussed in JCRN.

Also Japanese representatives to CCIRN (Coordinating Committee for Intercontinental Research Networks) and IEPG (Intercontinental Engineering Planning Group) are elected in JCRN. The corresponding JEPG/IP (Japan Engineering and Planning Group for IP internets) and JNIC (Japan Network Information Center) operate with the consensus of JCRN.

Another objective of JCRN is the promotion of internetworking in Japan and JCRN has held annual symposia to this end.

2. Japan Network Information Centre

JNIC was set up at the University of Tokyo Computer Centre in 1991 as a center of the whole Japanese internets. Domain names, IP addresses, and routing policies are administered by JNIC in consultation with the NSFNET NOC in the United States of America. To resolve IP addresses from domain names, JNIC uses BIND (Berkeley Internet Name Domain) software.

The top domain name for Japan is "jp" and the second-level domains under jp are as shown in Table 1. (The left-hand number indicates the number of organizations belonging to each domain.)

Table 1 — Second-level Domains Under jp

No. of Organizations	Domain	Organizations
452	co	companies
195	ac	academic institutions
40	go	government laboratories
39	or	public organizations
10	ad	network administration
3	ntt	
	nttdata	special domains
	kek	
739	total	

NOTABLE APPLICATIONS OF INTERNETS IN JAPAN

Since internetworking is relatively new in Japan, we do not see many applications yet. The following are some examples.

1. Remote use of Fujitsu AP1000

The AP1000 is an experimental massively parallel computer system designed by Fujitsu, the largest computer manufacturer in Japan. Each processor in AP1000 is a SPARC chip (15 MIPS; 8 MFLOPS) with 16 MB memory. Each AP1000 system can be configured with 16 to 1,024 processors. Fujitsu makes 4 AP1000 systems (one 512-processor system, one 128-processor system, and two 64-processor systems) available to WIDE users round-the-clock. Figure 6 shows the configuration.

2. GenomeNet for human gene data exchange

The GenomeNet is a special-purpose network setup for exchanging human genetic-analysis data among researchers. The project has its own 64 Kbps leased-lines between TISN, Tokyo, Kyoto, and Osaka universities, but it depends on WIDE, TISN, and JAIN for nationwide and overseas connection as shown in Fig. 7. The GenomeNet center at Kyoto University is now preparing for anonymous ftp with access to GenBank and EMBL databases. These are already available in the United States of America and Germany.

3. Distribution of Physics Preprints

In 1992, Kyoto University Computer Center stopped to support a preprint distribution (Fig. 8) service on a basic physics database called DESY/RIPF that had been compiled by DESY (Germany) and Yukawa Institute for Theoretical Physics of the University. The service is now offered on SPIRES (Stanford Public Information Retrieval System) on an IBM mainframe at YITP connected via BITNET and Internet with SLAC (Stanford, U.S.A.), FNAL (Fermi Lab in USA), SSCS (USA), LANL (Los Alamos, USA), CERN (Switzerland), DESY and KEK (Japan) as shown in Fig. 7. Papers written by researchers in each region served by each laboratory are distributed to other laboratories and deposited into their respective databases. Thus any researcher can retrieve and read any preprint anywhere in the world where the Internet/BITNET access is possible. E-mail can also be sent to the SPIRES system to get a preprint.

4. Inet Club

The Inet Club is a consortium of 205 JUNET member companies for overseas connection. While JUNET has 64 Kbps links to WIDE, the WIDE is only open to universities and WIDE sponsor companies (mostly related to computers and communications). So it was necessary for non-WIDE member companies to join forces to form a private club to share an international link. Inet Club was thus formed in 1987 with the help of the KDD laboratory. Currently, Inet Club uses high-speed TrailBlazer modems located in the KDD lab and UUCP protocol to make overseas telephone calls to uunet (USA), mcsun (Netherlands) and uknet (UK). The amount of network news subscribing to Usenet reaches 70 MB per month and they are distributed to other domestic sites on JUNET with the use of the TrailBlazer modems.

5. Problem and Needed Actions

For further promotion of internetworking in Japan, we still have many problems.

1. We must have greater public and financial support from government sources and private sectors. It is necessary to educate the general public and government officials on the significance of networking and personal communication on networks.

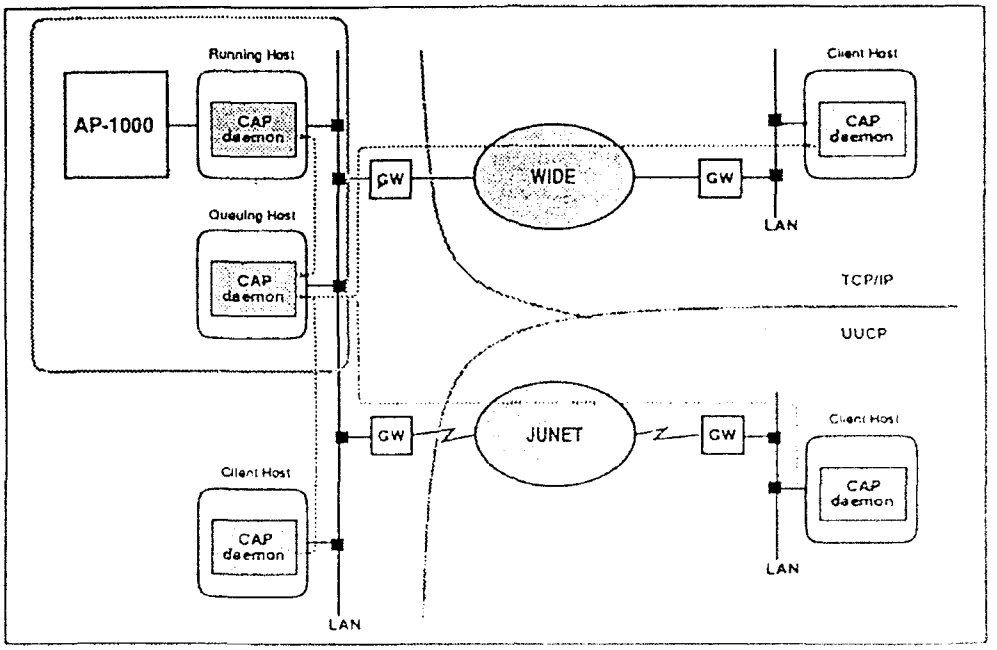

Fig. 6 — Access routes for Fujitsu AP1000
(from a paper by K. Inoue & O. Saito of Fujitsu)

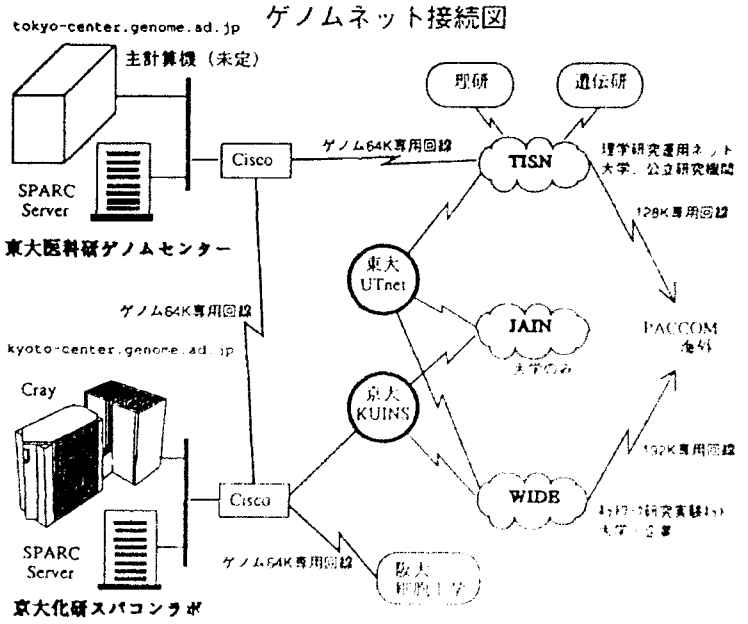

Fig. 7 — GenomeNet configuration
(as of January 1992)

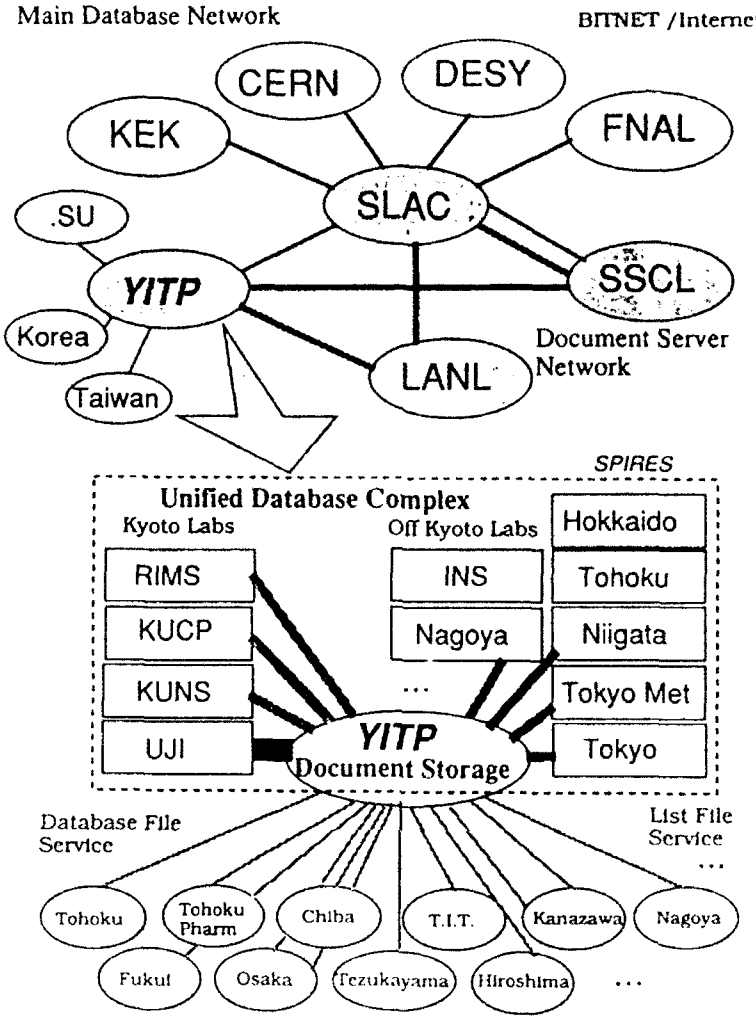

Fig. 8 — Physics preprint distribution network

2. We need more coordination between existing internets. To accomplish this, we must try to eliminate walls between universities and industries imposed by administrative barriers of the government.

3. Japan must increase the number of free (at no charge) accessible systems. The United States of America has many anonymous ftp servers, free-access database systems, and info-servers (mail-answering systems); however, Japan has more. This is not so easy in Japan because it involves not only cost, management, and change in consciousness, but there also is a language barrier (we need to prepare information in English!). We must note also that 'who-is' service (as available on nic.ddn.mil) is not available in Japan yet.

4. We need more applications software using networking and distributed environments. Japan still lags behind the United States of America and Europe in software development, and we do not yet have many client-server type software and groupware of our own design.

5. It is necessary to make our links faster. The top speed of our networks is only 192 Kbps for WAN and 1.5 Mbps for intercampus links. No plan exists for gigabit testbeds. Obviously, this is because the tariffs for data communication are too high. We need to give greater pressure to PTT and common carriers for lower tariffs.

6. We should try to increase the number of students and researchers in networking fields. Since human resources are limited, Japanese communication industries are concentrating their efforts mostly on B-ISDN (ATM) and OSI, leaving small room for other possibilities. The fact that Japanese-made routers and frame-relay equipment are just appearing is an indication of this narrowness of the industry pursuit. The education problem is also related to the lack of the public awareness as mentioned above.

7. It would be worthwhile to try to extend our links to Asian countries at Japan's expense. Japan has a substantial budget for ODA (Official Development Assistance). If we can spare only a fraction of the money for international academic internetworking, it will be very effective to promote international understanding. We should also have direct links to Europe.

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Dr. Haruhisa Ishida,
Tokyo University,
Professor, Computer Center
2-11-16 Yayogi, Bunkyo-ku
Tokyo 113

DOD SPIN-OFFS AID JAPANESE PRECISION MANUFACTURING

Daniel E. Whitney

Professor Yoshiharu Namba of Chubu University makes some of the flattest and smoothest surfaces in the world by using machines that he designed plus United States made numerical controllers and measuring instruments. "Most of the U.S. equipment I use is of interest only to the U.S. defense community. In Japan, we use it for commercial products. Regardless of where a VCR is made, the record/play head is made in Japan, because my method is used."

For over 20 years, Professor Namba has gathered world-wide technology and designed a series of remarkably high-precision diamond turning and fine-particle slurry grinding processes. Once he has proven the processes, he passes them on to industry. He is or has been a consultant to DoD and DoE (Los Alamos, Livermore) as well as U.S. and European industry (Polaroid, Gillette, Zeiss) plus optical and electronics firms in Japan.

Here is a summary of capabilities he discussed.

DIAMOND TURNING

By using a computer numerically controlled (CNC) machine tool made by Toyoda Machine Tool company, Professor Namba has made glass and nickel samples, 4 *in.* in diameter, that are flat to 0.1μ and have surface roughness of 15Å peak to valley. This machine is mounted on two layers of vibration isolation in a temperature controlled class 10,000 clean room. An Allen-Bradley controller issues 0.01μ step commands to the cutter. The evolving surface is monitored by a Hewlett-Packard interferometer. Finished surfaces are measured by a WYCO (Tucson, AZ) interferometric measuring machine. Other surface measuring methods used are scanning tunneling microscope (STM) and scanning force microscope (SFM).

A future application Professor Namba is working on is a super-light space X-ray telescope. The collectors would be made of fine polyamide films made by depositing dissolved polyamide onto an optically smooth nickel mandrel. When the plastic film hardens, it is supposed to be removed, forming a cylinder with an optically smooth interior.

He can make the mandrels but he has not solved two problems: how to get the plastic off the mandrel safely and how to mount it to a support structure that will have many concentric cylinders only 2 mm apart radially.

PRECISION GRINDING MACHINE

Toyoda built this machine to Professor Namba's specifications. The computer and CNC controller are all Japanese-made. The main feature is a spindle made of a glass-ceramic called Zerodur, made by Shott in Germany. Its thermal expansion coefficient is almost zero and well below that of Invar. Hydrostatic bearings support this shaft that spins on a vertical axis at 3650 RPM.

This machine can create 1.6Å RMS surface roughness on parts several inches in diameter by using a diamond grinder. He showed measurements made on a 200μ square region by China Lake Naval Weapons Center by using an SFM.

Professor Namba is interested in using this machine to make a variety of nonlinear optical parts from either organic materials or little-known single crystal called KTP. Their essential property is the ability to shift the frequency of laser light, especially from infrared (IR) to ultraviolet (UV).

An interesting application of the IR-UV frequency shifters is to make holes in polymers. This is typically

[1]Professor Namba visited London on 22 August 1992 and was interviewed by Dr. Daniel Whitney, Liaison Scientist for Manufacturing, and Dr. Cynthia Whitney of W.J. Schafer Associates, Inc. and the Tufts University Electro-Optics Center.

done by using relatively dangerous and costly eximer lasers, and the holes are made by vaporizing the polymer. He showed photos of the resulting holes, which are rough and have bubbles around their peripheries because of the excess heat. He uses a cheap and safe IR YAG diode laser, shifts its frequency to one that resonates with the polymer's bonds, and makes a very smooth flared hole. Using 500 pulses, 5 ns long each at a wavelength of 266 nm, and attaining an energy density of only 0.32 J/cm^2, he made 50μ diameter holes.

He did not mention an application but the one that occurs to me right away is drilling tiny *via* holes between layers of polymer interconnect structures used in multichip modules (MCMs). A major problem in MCM fabrication is the creation of accurate, smooth, and uniform vias. Eximer lasers are the current method of choice.

Professor Namba plans to use the grinder to make mirrors for laser fusion apparatus. Currently, such mirrors cost too much (¥30M or almost US$250,000 just to grind) and they are too rough. They cannot take more than 10 J/cm^2 without damage. His samples can take 20, but they are too small for use in laser fusion devices. Either many such pieces must be combined into one mirror or he will have to obtain a larger grinder.

FLOAT POLISHING MACHINE

This method is at least 10 years old, since he said Japanese VCR makers have used it that long to grind glass parts for read/write heads. The advantage of the method is that it causes very little damage to the surface. More surface damage permits the magnetic material to diffuse farther into the glass, thus causing the magnetic field to widen. A narrower field permits denser recording on the tape.

This polisher looks like a conventional lapping machine except that the parts and the lap do not touch each other. The samples are spun slowly over the lap with a few μ spacing. The grinding medium is very pure water with a small amount of pure silicon dioxide powder mixed in. The powder particles are about 70Å diameter. The lap is made of tin with concentric circular grooves and diamond-turned lands, and turns under the sample at 60 to 200 RPM. In about an hour he can make 5 in. diameter surfaces, 0.027μ flat, with 0.6Å RMS roughness. These surfaces have a laser damage limit of 30 J/cm^2.

CLOSED LOOP SYSTEM FOR GENERATING OPTICAL FIGURES

He calls it the first machine that can add and remove material. For removal he simply heats a region with an UV laser. For adding, he illuminates a metal-gas compound with the laser until it dissociates. A small amount of metal is deposited where the laser is shining. Professor Namba has used this to deposit a small bump feature 50μ square and 55 nm high in about 5000 layers of 0.1Å each. He does not know the crystal structure of such bumps. Possible applications include making compact disk press molds or precision electrodes for electro-discharge machining. They can be called *micro layering technology*.

HIS DESIGN FOR AN STM

Built by Seiko to Professor Namba's specifications, it has a novel property. The atomic probe is mounted on a microscope turret in place of one of the objective lenses. Thus, he can use the microscope to find the region he wants to probe, then switch in the STM. He says that he has solved the problem of boresighting the optical and atomic probe axes. This machine can measure 5 in. in diameter pieces.

This instrument is in a Class 10 cleanroom. The air downflow causes so much vibration that he has to shut it off during measurements.

GENERAL COMMENTS

Professor Namba feels that the Japanese approach to such high precision, high technology things is superior to that of the West. He cites these differences:

(a) In the West, only the defense industry is interested in such matters. The defense labs and large contractors spin off little firms to exploit a given technology. But these firms never grow because there is no commercial market. Thus they never get the money or skills to improve their technology. Japanese firms obtain this technology and improve it in-house until the western firms are outclassed.

The same thing happened in fabricating semiconductor equipment, and now is happening in precision CNC controllers: Japanese controllers have caught up with Allen-Bradley's, and the next generation will be better.

(b) Western research in optics is too theoretical, and not enough engineers understand geometric optics. Research is conducted in quantum optics, not what industry can use. In Japan, mechanical engineers learn optics after they graduate from the university, when the employers send them for specific optics training. This is typical of Japanese practice that capitalizes on the broad but shallow education given by the universities.

In addition, Japanese research has benefitted from a more stable funding base than U.S. research has. When the funding runs out, the teams break up; something that the Japanese try hard to avoid.

Thus, Professor Namba confirms several conclusions from my report on Japan last year [Whitney]. He also notes that the broad-shallow tradition continues in the companies as they rotate people through many different jobs. Westerners have asked me how deep is the knowledge and experience that develop in this environment. My answer, supported by Professor Namba, is that the expertise is shared by the group, which thus must be kept together. It is an *horizontal* concept of expertise, in contrast to the western *vertical* concept, where each individual is an expert in one narrow topic. The disadvantage of the vertical approach is that it does not generate leaders who understand the whole problem, except if the leader is a very rare type of person. You can't afford to wait until such a rare person comes along because too many are needed.

Nonetheless, Professor Namba comes to the United States to find laboratory expertise in optics, measuring instruments, and optics education, and the Japanese companies do the same. The best universities in this area, in his opinion, are at Tucson, Huntsville, Albuquerque, and Rochester. There used to be several in Japan, but only one of comparable quality is left. He does not know why. He also notes that Polaroid makes the world's best plastic aspheric lenses.

Point of Contact:

Professor Yoshiharu Namba
Department of Mechanical Engineering
Chubu University
1200 Matsumotocho, Kasugai
Aichi 487, JAPAN
Phone: 81-568-51-1111 EXT. 2306
FAX: 81-568-51-1141

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Dr. Daniel E. Whitney received his B.S., M.S., and Ph.D. degrees in mechanical engineering from MIT. He has been with the Charles Stark Draper Laboratory (CSDL) since 1974 and is currently in the Robotics and Assembly Systems Division. Before coming to CSDL he was an associate professor of mechanical engineering at MIT. At CSDL Dr. Whitney's research centers on assembly automation: part mating and assembly systems analysis, application of control theory to robot operations, supervision of robot assembly machine design and fabrication, trade-off analysis of automation systems, and producibility analysis of products. He also does industrial consulting on complex products and systems design and operation, including shipyards. Dr. Whitney holds a number of patents and is a Fellow of ASME and a Senior Member of IEEE.

THE FIFTH INTERNATIONAL CONFERENCE ON THE SCIENCE AND TECHNOLOGY OF ZIRCONIA

The conference, held in Melbourne, Australia, focussed on the latest developments in the science and technology of zirconia and zirconia-based ceramics with emphasis on phase transformations, processing and microstructural control, mechanical properties, defect structure, and electrolytic behavior. The conference highlighted the use of zirconia in high temperature solid oxide fuel cells and sensors; this application is reviewed in this report.

S.C. Singhal

INTRODUCTION

The Fifth International Conference on the Science and Technology of Zirconia (Z1RCONIA V) was held in Melbourne, Australia, on August 16-21, 1992. The conference was part of the International Ceramic Conference and Exhibition (AUSTCERAM 92) organized by the Australasian Ceramic Society and Victorian Ceramic Group with the endorsement of the International Ceramic Federation. AUSTCERAM 92 was attended by about 400 participants representing 24 different nations. Out of these, about one-third were from outside Australia. The United States had 30 representatives and Japan about 50. The extensive technical program of AUSTCERAM 92 covered an exceptional range of topics, from raw materials, traditional ceramics, and refractories through to the many aspects of advanced ceramics, superconductors, and fuel cells. A trade exhibition was also organized as part of the conference, where mainly Australian companies and government organizations displayed a broad spectrum of products and services including raw materials, kilns, ovens, heavy clay plant equipment, analytical and nondestructive testing equipment, machine tools and robotics, and engineered ceramic products. The conference theme was *Adding the Value,* translating the advances in ceramic technology into products and processes for the real world. This theme was especially appropriate for Australia, which is rich in mineral resources but still needs to improve its track record in exploiting this advantage by adding value through downstream processing.

This report focuses on the Fifth International Conference on the Science and Technology of Zirconia (ZIRCONIA V) which ran concurrently with AUSTCERAM 92. Previous ZIRCONIA conferences were held in 1980, Cleveland, Ohio, U.S.A.; 1983, Stuttgart, Germany; 1986, Tokyo, Japan; and 1989, Anaheim, California, U.S.A. Australia was chosen as the host for ZIRCONIA V as a tribute to the leading role its scientists have played in developing Zirconia technology (including the understanding and application of transformation toughening), and to Australia's abundant zircon reserves and its processing and fabrication technologies. One hundred and eighteen technical papers presented in ZIRCONIA V were grouped under five topics:

1. Phase Transformations
2. Processing and Microstructural Control
3. Mechanical Properties
4. Electrolyte Behavior and Defects, and
5. Fuel Cells and Sensors.

The 35 papers presented in the last two groups dealing with the electrolytic behavior of zirconia and its use in high temperature fuel cells and sensors are reviewed in this report.

BACKGROUND

The high oxygen ion conductivity over wide ranges of temperature and oxygen pressure in stabilized zirconia has led to its use as a solid oxide electrolyte in a variety of electrochemical applications. Zirconia-based oxygen sensors are widely used in combustion control, especially in automobiles, atmosphere control in furnaces, and as monitors of oxygen concentration in molten metals. Other applications include electrochemical pumps for control of oxygen potential, steam electrolyzers and high temperature solid oxide fuel cells (SOFC). High temperature fuel cells using yttria stabilized zirconia electrolyte offer a clean, pollution-free technology to electrochemically generated electricity at high efficiencies. These fuel cells provide many advantages over traditional energy conversion systems; these include high efficiency, reliability, modularity, fuel adaptability, and very low levels of NO_x and SO_x emissions. Furthermore, because of their high temperature of operation ($\sim$1000°C), these cells can be operated directly on natural gas, eliminating the need for an expensive, external reformer system. These fuel cells also produce high-quality exhaust heat that can be used for process heat or a bottoming electric power cycle to further increase the overall efficiency.

A solid oxide fuel cell essentially consists of two porous electrodes separated by a dense, oxygen ion conducting Zirconia-based electrolyte. Oxygen supplied at the cathode (air electrode) reacts with incoming electrons from the external circuit to form oxygen ions, which migrate to the anode (fuel electrode) through the oxygen ion conducting electrolyte. At the anode, oxygen ions combine with hydrogen (and carbon monoxide) in the fuel to form water (and/or carbon dioxide) thus generating electricity. To keep the cell resistance low, the electrolyte in the various solid oxide fuel cell designs is fabricated in the form of a thin film. The air electrode is generally made from a perovskite structure ceramic such as strontium-doped lanthanum manganite and the fuel electrode is generally a nickel/yttria-stabilized zirconia cermet.

Solid oxide fuel cells of several different designs are presently under development: these include planar, monolithic, and tubular. The current status of all three types was reviewed at the conference by participants from the United States, Japan, Europe, Australia and New Zealand. Following sections summarize the SOFC activities in and presentations from the United States, Japan, Europe, and Australia/New Zealand.

UNITED STATES

The Plenary Session opened with an invited lecture by the author of this report; the lecture was titled, "Recent Progress in Zirconia-Based Fuel Cells for Power Generation". The author reviewed the materials and fabrication processes used to manufacture solid oxide fuel cells of tubular geometry and the field testing of electrical generators built by using such cells. The most progress to date has been achieved with the tubular geometry developed by the Westinghouse Electric Corporation. In this design, the active cell components (electrodes, electrolyte and interconnection) are deposited in the form of thin layers on a ceramic support tube. Westinghouse has successfully fabricated, employed, and tested these cells for power generation in successively larger generators since 1984. In early 1992, a 25 kW dc power generator, consisting of 1,152 cells of 50 cm active length, was fabricated and delivered for testing at Rokko Island, near Osaka, Japan, in a joint program with Kansai Electric Power Company, Osaka Gas Company, and Tokyo Gas Company. A second 25 kW system, a cogeneration unit supported by Osaka Gas Company and Tokyo Gas Company, has also been fabricated; this system will supply ac power and intermediate pressure steam to another test site in Japan. These two 25 kW units manufactured by Westinghouse represent a major milestone in the commercialization of Zirconia-based fuel cells for large scale (multi megawatt) power generation toward the end of this century.

In addition to Westinghouse Electric Corporation, work in the United States on solid oxide fuel cells is conducted at Ceramatec, Inc. of Salt Lake City, Utah, and Allied-Signal Aerospace Company of Torrance, California. Dr. Ashok Khandkar of Ceramatec presented a paper titled, "Modelling, Design, and Performance of SOFC's." This paper reviewed the design and performance of planar solid oxide fuel cells. In this design, the cell components are configured as thin, flat plates. The planar cell design offers improved power density but requires high temperature gas seals at the edges of the plates to isolate oxidant (air or oxygen) from fuel. The difficulty in successfully developing such high temperature seals has limited the development and use of planar design cells for SOFC generators.

Dr. N. Q. Minh of Allied-Signal Aerospace Company presented a paper titled, "Materials, Fabrication and Development Trends for Solid Oxide Fuel Cells." He reviewed the fabrication processes used to fabricate the required ceramic structures for different SOFC designs. Allied-Signal is concentrating on the development of monolithic-type solid-oxide fuel cell, originally conceived at the Argonne National Laboratory. In this design, the different cell components are fabricated as thin layers; the cell consists of a honeycomb-like array of adjacent fuel and oxidant channels. Even though the monolithic solid oxide fuel cells offer potentially the highest power density of all SOFC designs, their fabrication involving cosintering of the ceramic cell components at elevated temperatures has proven to be a formidable task. As a result, the development of electric generators using monolithic solid oxide fuel cells has not progressed very far.

The only other presentation from the United States of America, titled, "Photophysics of Stabilized Zirconia," was by Dr. E. D. Wachsman of SRI International, Menlo Park, California. He presented optical absorption and luminescence data on yttria-stabilized Zirconia. This process is useful to gain an understanding of the effects of dopants on electrical conductivity and reactivity of zirconia-based electrolytes.

JAPAN

Japan has an ongoing large development effort related to solid oxide fuel cells. Professor H. Tagawa of Yokohama National University, who is also the President of the Solid Oxide Fuel Cell Society of Japan, reviewed the SOFC related R&D activities in Japan. These activities range from basic research to the development of 1-10 kW size electric generators. Basic research on materials and electrode kinetics has been carried out at several universities for a long time. Two national laboratories, the Electrotechnical Laboratory and the National Chemical Laboratory for Industry, both located in Tsukuba District near Tokyo, have also performed research on materials, processing and stack fabrication. Many companies are also interested in developing solid oxide fuel cells. The greatest amount of work appears to be conducted by Mitsubishi Heavy Industries Ltd. at its Nagasaki, Kobe and Takasago works. A paper, "Development of the Solid Oxide Fuel Cells," by I. Osada, S. Uchida and F. Nanjou of Mitsubishi Heavy Industries Ltd. reviewed the progress in three types of SOFC's (tubular, planar, and MOLB type) that they are developing. In 1990 and again in 1991, Mitsubishi tested a 1 kW generator using tubular SOFC. A 1 kW module test of the MOLB type cell is planned for 1992. The planar design cells are still in single cell development stage. Mitsubishi also presented a paper on a reversible type cell that can operate in steam electrolysis mode to produce hydrogen and in electric generation mode by using this hydrogen as fuel. The development of this type of reversible cell is still in its early stages.

Dr. T. Hlkita of Tokyo Gas Company Ltd. reviewed, "Research and Development of Planar Solid Oxide Fuel Cells at Tokyo Gas." Tokyo Gas Company is conducting research and development activities on planar SOFCs while continuing evaluation of Westinghouse's tubular SOFC systems, initially a 3 kW system in 1987-88, and more recently 25 kW systems. Their R&D activities are concentrating on materials, fabrication processes, and performance testing of planar design cells.

Other papers from Japan included activities on materials properties, fabrication processes, and performance characteristics of solid oxide fuel cells and sensors. These papers are listed below:

1. "Solid Oxide Fuel Cell with a Thin Stabilized Zirconia Film Supported on an Electrode Substrate," K. Eguchi, T. Setoguchi, S. Tamura, and H. Arai, Kyushu University.

2. "ZrO_2 Sheet," Y. Hoshi, K. Kaga, Y. Kimura, and M. Obitsu, Nissan Chemical Industries, Ltd.

3. "Anomalous Oxygen Evolution from Zirconia Cells at the Transient State," J. Mizusaki, H. Narita, H. Tagawa, M. Katou, and K. Hirano, Yokohama National University.

4. "Reaction Between Lanthanum Chromites and Yttria Stabilized Zirconia," M. Mori, H. Itoh, N. Mori, and T. Abe, Central Research Institute of Electric Power Industry; and O. Yamamoto, Y. Takeda and N. Imanishii, Mie University.

5. "Measurement of Water Vapor Pressure in the Vicinity of the SOFC Anode During Discharge," M. Nagata and H. Iwahara, Nagoya University.

6. "Interfacial Evaluation of Solid Oxide Fuel Cell Fabricated by Plasma Spraying Processes," Y. Ohio, K. Kaga, K. Tsukamoto, F. Uchiyama, T. Okuo, and A. Monma, Electrotechnical Laboratory.

7. "Chemical Stability of (La,Ca) CrO_3 Interconnects of Solid Oxide Fuel Cell," N. Sakai, T. Kawada, H. Yokokawa, and M. Dokiya, National Chemical Laboratory for Industry.

8. "Zirconia Based Oxide Ion Conductors in Solid Oxide Fuel Cells," O. Yamamoto, T. Kawahara, Y. Takeda, N. Imanishi, and Y. Sakakl, Mie University.

9. "Chemical Thermodynamic Stabilities of the Interface," H. Yokokawa, N. Sakai, T. Kawada, and M. Dokiya, National Chemical Laboratory for Industry.

10. "Determination of Oxygen Self Diffusion Coefficients in Yttria Stabilized Zirconia System by Raman Spectroscopy," B-K. Kim, S-J. Park and H-O. Hamaguchi, Kanagawa Academy of Science and Technology.

EUROPE

Professor Brian Steele of Imperial College, London, in a keynote paper, reviewed the solid oxide fuel cell related R&D in Europe. Professor Steele also presented another paper, "SOFC Design Requirements for Zirconia Electrolyte Components," where he discussed electrical and mechanical property requirements of electrolyte for different design SOFCs. Compared to that in the United States of America and in Japan, the industrial development effort in Europe on solid oxide fuel cells is small. Siemens in Germany probably has the largest European program to develop planar type SOFC; however, they were not represented at the conference. In general, the participation from Europe was limited to academic people who presented many excellent papers on the fundamental studies of ionic conduction, oxygen diffusion, defect structure and fabrication of Zirconia and zirconia-based materials. This is evident from the titles of the papers listed below:

1. "Oxygen Permeation Through Thin Dense EVD YSZ Membranes," H. W. Brinkman, G. Z. Ceo, J. Meijerink, K. J. de Vries, A. J. A. Winnubst, and A. J. Burggraaf, University of Twente, The Netherlands.

2. "The Growth of Electrochemical Vapor Deposited (EVD) YSZ Films," J. P. Dekker, V. E. J. van Dieten, and J. Schoonman, Delft University of Technology, The Netherlands.

3. "Mixed Conduction and Oxygen Permeation of ZrO_2-$Tb_2O_{3.5}$-Y_2O_3 Solid Solutions," G. Z. Cao, X. Q. Liu, H. W. Brinkman, K. J. de Vries, A. J. A. Winnubst, and A. J. Burggraaf, University of Twente, The Netherlands.

4. "Ionic Conductivity of Tetragonal and Cubic ZrO_2 Doped with In_2O_3," L. J. Gauckler, K. Sasaki, P. Bohac, and A. Orliukas, Swiss Federal Institute of Technology, Switzerland.

5. "Impedance Spectroscopy of Microstructure Defects and Crack Characterization," M. Kleitz, C. Pescher and L. Dessemond, Laboratoire d'Ionique et d'Electrochimie du Solide de Grenoble, France.

6. "Spectroscopic and Microstructural Studies of the Electronic Defects in Doped Monoclinic, Tetragonal, and Cubic Zirconia Polycrystals," P. Kountouros, N. Nicoloso, and M. Haberkern, Max-Planck Institut fur Metallforschung, Germany.

7. "Ionic and Electronic Conductivity of TiO_2-Y_2O_3-Stabilized Tetragonal Zirconia Polycrystals," P. Kountouros and H. Schubert, Max-Planck Institut fur Metallforschung; A. Kopp and W. Weppner, Max-Planck Institut fur Festkorperforschung, Germany.

8. "Atomic Defects in Yttria-Stabilized and Calcia Stabilized Cubic Zirconia," M. Weller, Max-Planck, Institut fur Metallforschung, Germany.

9. "Mechanical and Dielectric Loss Measurements in Tetragonal Zirconia Ceramics," M. Weller, H. Schubert, and P. Kountouros, Max-Planck Institut fur Metallforschung, Germany.

10. "Amperometric Tetragonal Zirconia Sensors," B. Y. Liaw, J. Liu, and W. Weppner, Max-Planck Institut fur Festkorperforschung, Germany.

11. "Solid State Limiting Current Sensor for CO_2 Determination," C. M. Mari, D. Narducci, and L. Facheris, University of Milan, Italy.

AUSTRALIA/NEW ZEALAND

The technical organization of the ZIRCONIA V conference was largely the effort of its three

cochairmen from the Division of Materials Science and Technology, CSIRO, Australia: Drs. S. P. S. Badwal, M. J. Bannister, and R. H. J. Hannink. Dr. Badwal is the leading researcher in Australia on the electrolytic properties of zirconia and its use in solid oxide fuel cells. The SOFC R&D activity in Australia was reviewed by Dr. K. Foger, an associate of Dr. Badwal at CSIRO. Based on CSIRO's expertise in zirconia technology, a company, Ceramic Fuel Cells Ltd., has recently been formed to provide a focus for research, development and commercialization of solid oxide fuel cell technology in Australia. A consortium consisting of CSIRO, BHP, Pacific Power NSW, Energy Research and Development Corporation and Strategic Research Foundation will provide initial funding for research and development of solid oxide fuel cells. CSIRO, Division of Materials Science and Technology is the prime research--subcontractor with Ceramic Fuel Cells Ltd. Currently most company R&D work is performed there and some at BHP Melbourne Research Laboratories. The company is still in the formation stage.

In addition to the review paper by Dr. Foger, following three papers were presented from Australia:

1. "Impedance Spectroscopy and Grain Boundary Segregation in Zirconia-Based Materials: Effect of Sintering Temperature and Impurities," S. P. S. Badwal, CSIRO.

2. "Kinetics and Mechanism of Hydrogen Oxidation on Nickel Electrodes at 1000°C," S. P. Jiang, CSIRO.

3. "A Probe for Measuring Oxygen Fugacity in Molten Glass," J. Ji and M. P. Brungs, University of New South Wales.

A small university research program on SOFC has recently been initiated in New Zealand also. Professors N. M. Sammes and M. B. Phillipps of the University of Waikato, Hamilton, presented a paper titled, "Selection, Fabrication and Properties of Electrodes Used in High Temperature Fuel Cells." This program is still in its infancy.

SUMMARY

The Fifth International Conference on the Science and Technology of Zirconia was very well organized and truly international in character. The use of zirconia in high-temperature solid oxide fuel cells intended for power generation has reached the precommercialization stage with 25 kW electric generators being field tested by electric and gas utilities. United States (Westinghouse Electric Corporation) is in the forefront of this technology; however, large development effort is also underway in Japan as was evident from the large Japanese participation at the conference. When fully commercialized, the zirconia-based fuel cell systems are expected to serve a wide range of power and heat applications, such as large-scale power generation by electric and gas utilities and industrial cogeneration.

Dr. Subhash C. Singhal is Manager of Fuel Cell Technology at the Science and Technology Center of the Westinghouse Electric Corporation in Pittsburgh, Pennsylvania, U.S.A. He received his PhD. (1969) in Materials Science at the University of Pennsylvania, Philadelphia, Pennsylvania. He also holds a M.B.A. degree (1977) from the University of Pittsburgh, Pittsburgh, Pennsylvania. Since 1971, he has been, first a scientist and then Manager — High Temperature Materials and Manager — Advanced Materials at the Westinghouse Electric Corporation's Science and Technology Center in Pittsburgh, Pennsylvania. His research during this period focussed on advanced ceramic, metallic and composite materials for use in various energy conversion systems including gas turbines, steam turbines, coal-gasification systems and fuel cells. Since 1984, he has been responsible for the development of the solid oxide fuel cell technology in which Westinghouse Electric Corporation is the recognized world's leader. Dr. Singhal has written over 40 published papers and numerous technical reports. He has edited 4 books and has been issued 10 patents. He has given over 75 presentations world-wide, many invited and keynote talks and plenary lectures, at professional society meetings, international conferences and symposia, and universities. He is a member of the American Ceramic Society, The Metallurgical Society, and ASM International, and serves on the Board of Directors of The Electrochemical Society.

THE THIRD INTERNATIONAL CONFERENCE ON COLD FUSION: SCRUTINY, INVECTIVE, AND PROGRESS

Three and one-half years after the dramatic announcement of spontaneous generation of "excess heat" during the electrolysis of deuterium-substituted lithium hydroxide-heavy water electrolyte using Pd electrodes, significant progress in sorting out scientific fact from supposition or error has been reported. In Asia, scientists from Japan, Peoples Republic of China, India, Russia, and Taiwan have reported strong or compelling evidence that excess heat is produced spontaneously in this and other systems, and is accompanied with the weak emission of nuclear particles that are normally associated with deuterium nuclear-fusion reactions. While the excess power-density levels approaching 1 kW/cm^3, which were reported in 1989, have not been reproduced or quantitatively verified, power levels of order 0.1-10 W/cm^3 have been reported by many researchers using a number of different experimental arrangements and various substances. However, a huge discrepancy remains between the magnitude of excess power generation reported and the amount of energy released by the associated countable nuclear-reaction events. Among many suggested theoretical explanations, none as yet has claimed quantitative or even qualitative agreement with all aspects of experiment.

Victor Rehn and Iqbal Ahmad

INTRODUCTION

October 22-25, 1992 were four hot days in the otherwise pleasant surroundings of the Nagoya Congress Center, Nagoya, Japan. About 350 persons attended the Third International Conference on Cold Fusion and meticulously discussed the 133 papers (30 presented orally) from many nations. Attitudes of the participants ranged from derisively critical to exuberantly enthusiastic, with the median cautiously optimistic. One invited presentation was so severely critical that evoked an apology from the conference organizer, Dr. Hideo Ikegami [1] for "such a nonscientific paper."

Some of the behavior resembled that of fans at an European soccer game, or hockey players in America, rather than the usually sober, subtly contentious behavior of scientists at typical international scientific conferences. However, amid the inappropriate behavior, scientific research results were reported, reviewed, and discussed at length and in detail. In our opinion, evidence reported at this conference was so convincing as to mark the emergence of cold fusion from the shadows of derisive skepticism into the bright light of legitimate scientific enquiry.

BACKGROUND

In 1989 Martin Fleishmann and Stanley Pons, working at the University of Utah, announced that electrolysis using a Pd cathode with an electrolyte (0.1 molar solution of LiOD in heavy water, D_2O) generates heat much in excess of what could be

predicted from the resistive heating and the electrochemical energy involved.* They reported power densities greater than 20 W/cm³ of cathode volume. They claimed that such excess heat energy could be generated only from nuclear reactions occurring in the Pd cathode.

Although the claim was immediately supported by Steven E. Jones of Bringham Young University, and a few other more ambiguous reports, most groups, including Pons and Fleishmann, could not reproduce the reported excess heat. Serious challenges were made to the claim of nuclear-fusion reactions by pointing out the high level of nuclear-reaction products (neutrons, tritium, and helium) that would be required if nuclear fusion was the source of the amount of excess heat reported.

The First International Progress Review of Anomalous Nuclear Effects in Deuterium/Solid Systems was held in Provo, Utah, in October, 1990. Confusion and controversy permeated the scientific community, culminating in distrust and suspicion of the integrity of the researchers involved. A review presented by Douglas R. O. Morrison of CERN at the World Hydrogen Energy Conference in Honolulu, HI in 1990 relegated *cold fusion* to pathological science, alongside the infamous N-ray *discovery* eight decades earlier. The term *cold fusion* became taboo, particularly in the United States of America, where most research funding was curtailed, especially by the U.S. Government agencies.

In spite of this attitude, and in spite of the lack of reproducibility and control of *cold fusion*, many scientists agreed that excess heat and low levels of nuclear reaction products were *sometimes* observed. Research continued in Japan, Italy, USSR, China, and India. Even in the United States of America, the Electric Power Research Institute continued to support research at Stanford Research Institute (Michael McKubre) and Texas A&M University (John Bockris). Individual researchers such as Steven E. Jones at Bringham Young, Melvin Miles at the Naval Weapons Center, China Lake, and Edmund Storms at Los Alamos National Laboratory continued research at a low level.

The Second International Conference on Cold Fusion was held in Como, Italy, in June, 1991, followed by an International Symposium on Nonlinear Phenomena in Electromagnetic Field in Nagoya, Japan, in January, 1992. Other reports were published in J. Fusion Energy, Fusion Technology, J. Phys. Soc Japan, Nature, and elsewhere. According to Morrison, 728 papers were published on the subject between the original announcement of Pons and Fleishmann in 1989, and October 10, 1992.

Many papers have confirmed cold-fusion phenomena, but none have been so clear as to constitute generally acceptable scientific proof that nuclear fusion does occur near room temperature in metals. It was made clear, however, what measurements are needed to provide the needed convincing scientific proof.

Two of the more important advances in the understanding of *cold fusion* phenomena prior to the Nagoya conference were achieved by Akito Takahashi and coworkers from Osaka University, Japan, and by Eiichi Yamaguchi and Takashi Nishioka of Nippon Telegraph and Telephone, Ltd, (NTT) Japan.

Takahashi reported refinements of the technique used by Pons and Fleishmann for observing excess heat. In concurrence with McKubre, and with Keiji Kunimatsu, Takahashi emphasized the measurement of the amount of deuterium loaded into the Pd electrode, and the use of a periodic high-low current during electrolysis.

Takahashi reported observing neutron emission at low levels, anomalous tritium production, and formation of He gas at the Pd electrode surface. The observed neutron-energy spectrum supported the occurrence of fusion events, albeit at far too low a level for explanation of the magnitude of excess heat generation observed.

Yamaguchi and Nishioka reported their observation of cold-fusion reactions in a nonelectrolysis environment. They reported high-vacuum studies of deuterium- and hydrogen-loaded Pd plates that had been coated on one side with Au and on the other side with MnO_x in order to trap and control the deuterium (or hydrogen) within the Pd plates.

Yamaguchi and Nishioka reported concurrent observation of five associated phenomena:

(1) neutron emission bursts (up to 2×10^6 per second);

(2) explosive gas evolution;

(3) uniform warping and plastic deformation of the sample;

(4) the generation of *excess heat* sufficient to heat the Pd plates to more than 700°C; and

* LiOD is referred to by some in this field as "lithium deuterate".

(5) emission of high-energy ($\leq$3 MeV) charged particles.*

The Como conference had little impact on the attitude of the general scientific community toward *cold fusion*. In the first part of 1992, the Takahashi group published a series of papers reporting very careful experiments that showed improved reproducibility of the excess-heat observation at the 150 W/cm^3 level. In addition, low levels of ^{3}H (tritium) emission was reported.

Takahashi and coworkers suggested a theoretical explanation of *cold fusion* in metals to account for the fast-neutron energy spectrum observed. A new concept was suggested: Nuclear fusion reactions involving clusters of two, three or four deuterons or protons colocated near a tetrahedral site of the face-centered cubic (FCC) Pd lattice.

These and other reports from China, Russia, Italy and the United States of America produced a stimulating background for the Third International Conference on Cold Fusion. In Japan, the atmosphere was further charged by news reports indicating that Japan's Ministry of International Trade and Industry (MITI) would consider the results reported at the Conference carefully in formulating plans for possible future investment in research in the field. MITI publicly identified four key factors in their decision:

- detection of neutrons and tritium
- confirmation of excess-energy production
- reproducibility of the results in other laboratories, and
- progress in understanding the physical mechanism.

NUCLEAR ACTIVITY

The paper by Eiichi Yamaguchi and Takashi Nishioka [2] of NTT was highlight of the Third Conference. As mentioned above, in their previous research five concurrent measurements were made to characterize the process giving rise to spontaneous heating of the coated Pd plates. In their current report, a sixth critical concurrent observation was added. Using a high-resolution Extrel mass spectrometry system, they obtained high-resolution mass analysis of the gases evolved from the Pd during excess-heat generation.

These data clearly show the ^{4}He isotope, as distinguished from other mass-4 isotopes of molecular hydrogen: ^{1}H^{3}H (proton-triton), and ^{2}H$_2$ (two deuterons, or deuterium). Both of these hydrogen-molecule isotopes have nominal mass of 4 AMU, but differ in actual mass from ^{4}He by as little as 0.1% because of the lower nuclear binding energy. *In situ* calibration runs of the mass spectrometer demonstrate mass resolution of better than 0.01%.

Yamaguchi and Nishioka report that ^{4}He and ^{1}H^{3}H gases are not present in their turbomolecularly pumped chamber unless excess heat generation is occurring in the Pd. The deuterium gas used for *loading* the Pd plate was analyzed *in situ*, and found to contain no detectable ^{4}He. The conclusion is that these exotic gaseous isotopes (^{4}He and ^{1}H^{3}H) originate from a *nuclear reaction* with in the Pd:D, and emanate from the Pd during the explosive gas releases that occur only while excess heat is being generated.

In terms of reproducibility, NTT reported that starting in August, five consecutive runs, about a week apart from each other, produced essentially identical results. Other experimenters, at the conference, reported mixed reproducibility. Professor X. C. Li from Tsinghua University, Peking, P. R. China, reported 100% reproducibility, but other researchers reported difficulty in reproducing previously reported excess-heat generation rates. Fleishmann reported that they have never reproduced the high level of excess heat that they observed in 1989. Many researchers reported to have observed excess heat at the range 0.1-10 W/cm^3.

Yamaguchi and Nishioka had nothing to report about the possibility of ^{3}He generation. They plan to retune the EXTREL mass spectrometer for the mass-3 region soon to answer this question experimentally. The generation of ^{3}He and ^{3}H is an important question bearing on which of various possible nuclear reactions may be occurring.

The charged-particle results in the NTT experiment are less clear. The charged particle with energy near 3 MeV that was reported previously has been identified as a proton. An alpha-particle peak at 6 MeV is now suspected to be an artifice. The count rates are low in both cases, but especially low for the alpha peak. Also, reproducibility of charged-particle count rates has not been impressive.

It must be clearly noted that, although nuclear activity concurrent with the generation of excess heat seems to have been proved conclusively in the NTT experiments, no one at the conference claimed to

* E. Yamaguchi & T. Nishioka, Jpn J. Appl. Phys. 29 (1990), L666; Proc. Int. Progress Review, "Anomalous Nuclear Effects in Solid/Deuterium Systems" (Provo, UT, Oct 1990), p. 354.

account quantitatively for the excess-heat generation directly from nuclear energy. A major puzzle now is the source of so much excess heat, if not directly from nuclear sources.

In the Yamaguchi-Nishioka experiment and others, neutron count rates up to 2×10^6 per second were observed in bursts. Although their detector efficiency was not discussed, it may be assumed to be a few percent. In later discussions with Yamaguchi, he stated that the reported count rate had been adjusted to account for solid angle, and represents the total for 4π steradians. These neutrons represent at most 10^8 nuclear fusion events per second. However, nuclear-fusion events of order $>10^{11}$/s or more, are required if the watts of excess heat generated are to be attributed entirely to nuclear reactions.

The observation of nuclear reaction products is well correlated with excess-heat generation, explosive gas release, and uniform bi-axial warping, and plastic deformation of the sample. However, the count rates of nuclear-reaction products observed are inadequate to account for the magnitude of excess-heat generation reported.

This may be illustrated by considering typical fusion reactions as follows. The energy release in each case is well known from nuclear-structure studies over the past 60 years:

i) d + d=t(1.0)+ p(3.02)
ii) d + d = ^{4}He(23.85)
iii) d + d = ^{3}He(0.8) + n(2.45)

d denotes deuteron, t denotes triton, and p denotes proton, all nuclei of hydrogen. n denotes neutron. The values in parentheses are the energy release per event in MeV.) Using example ii, which has the largest energy release per nuclear event, 2.6×10^{11} nuclear events are needed per second per Watt, on the assumption that all the energy released is converted into heat, and none is carried out of the sample as kinetic energy of the escaping particle. A neutron count rate of 2×10^6 per second, corrected for detection efficiency and solid-angle of collection, could imply at most 10^{10} nuclear events per second, but the magnitude of the discrepancy is glaring. The discrepancy has proved difficult to account for without assuming a new kind of nuclear process that does not lead to any of the detected nuclear-reaction products.

At this time, the results of the Yamaguchi-Nishioka experiment show that especially strong evidence that some kinds of nuclear reactions do occur in the Pd:D system (and most likely other systems, as well) under appropriate conditions.* In accepting this as a fact of nature, one must also accept the need for a re-examination of the interaction of nuclear states with electronic and other states in solids.

Are new physical concepts active in these systems (such as multibody or other solid-state fusion,) or is some standard approximation of physics being violated (slightly) in certain circumstances? Within physics, the implications are far-reaching. Within technology and society also, there may be far-reaching implications.

Deuterium is abundant on Earth, it comprises 0.015% of all hydrogen, the most abundant element in seawater, and in the astronomical universe. While Pd is a rare and precious metal, Ti and other hosts may work as well. The excess power density recently reported has usually been quite low. Yamaguchi did not discuss the power density obtainable from his Pd plates. However, the NTT experimenters have reported that the temperature of the 3-inch Pd plates rose to as high as 800°C. Temperatures above 500°C can be used to provide high-grade thermal energy useable in efficient commercial production of electricity, for example. Even low-grade thermal energy, if cheap and safe enough, can be useful in architectural space heating, seawater desalination, and other industrial processing.

Because we consider the NTT experiment to be a critical test of nuclear activity concurrent with the generation of excess heat by Pd-deuterium systems, we summarize the significant experimental details.

THE NTT EXPERIMENT

The NTT Pd plates are prepared in a separate vacuum chamber that is normally used for gold evaporation:

First, a thin layer of MnO_x is deposited on a stainless-steel heater.

Second, the $30 \times 30 \times 1$ mm Pd plates are mounted in the vacuum chamber and exposed to 1/2 atm of 99.9% pure deuterium gas at room temperature. It is estimated that the deuterium loading factor (the concentration of deuterium atoms absorbed within

* From Pd:H samples, no nuclear reaction products were observed by the NTT researchers. However, explosive gas releases, sample warping, and excess-heat production (smaller) were observed in Pd:H samples, as well.

the Pd normalized per Pd atom) is about 0.48. In the case of hydrogen exposure, the loading factor achieved by this process is estimated to be 0.56. (These values are considerably lower than 0.83, the loading factor generally is considered to be threshold for excess heat production in Pd electrolysis experiments.)

Third, the top surfaces of the Pd plates are rapidly heated by contact to the MnO_x-coated stainless-steel heater, and cooled to room temperature.

Fourth, an MnO_x film 10-20 nm thick is deposited on the surface through electron-beam evaporator, and is followed by 18-24 hr exposure to deuterium gas. The MnO_x film provides a surface barrier for out-diffusion of deuterons, and also a controllable potential well for collection of deuterons with appropriate bias (deuteron-accumulation layer.)

Fifth, after evacuating the chamber to a pressure $p \leq 10^{-5}$ T, a gold film, 200 nm thick, is deposited on the opposite side of the Pd plate from the MnO_x film. This film provides a surface barrier for out-diffusion of deuterons without the possible deuteron-accumulation layer.

Three samples, so prepared, are loaded at once into a UHV chamber. Both standard quadrupolar and high-resolution mass spectrometers are attached to the chamber along with a commercial ^{3}He neutron detector. The samples are mounted with a strain gage attached (on the Au-coated surface), and a Si charged-particle detector (depletion layer depth: 300 μm). Several thermocouples are used for temperature measurement.

The experiment is controlled by applying current normal to the Pd plate, at the level of 0.5 to 0.8 A/cm^2, or by sample heating. In both cases, it is suggested that migration of deuterium increases the deuterium-loading factor in the accumulation layer beneath the MnO_x insulator. With sample heating, the temperature gradient is said to be the force driving the deuterium migration.

Explosive gas evolution, warping and plastic deformation of the Pd, and excess-heat generation occur with "100% reproducibility," a welcome situation in a field replete with reports of nonreproducibility. The detection of ^{4}He was added to the experiment only last August, but has been reproducible in five consecutive runs one week apart.

Control experiments using ordinary hydrogen gas loading of the Pd have been conducted as well. In these experiments, excess heat was observed in lesser amounts as well, but no accompanying nuclear-reaction products have been detected.

OTHER EXPERIMENTS

The most quoted experimental research in cold fusion in Japan is that of Akito Takahashi [3] and coworkers. Their well publicized contribution to cold-fusion experimental technique has been copied by several other groups in various countries. The group presented three papers at the Nagoya conference, which updated several of their previous reports.

Previously, Professor Takahashi had suggested that if nuclear fusion can occur in solids in spite of the large internuclear distances, then one may consider whether multibody fusion events might also occur. For the Pd:D and Ti:D systems, Professor Takahashi has suggested events that involve three and four nuclei of hydrogen or deuterium, and that result in emission of reaction products such as ^{1}H, ^{2}H, ^{3}H, ^{3}He, and ^{4}He.

In his invited presentation, Dr. Takahashi asserted that cold fusion *is proved*, that three-body fusion products have been identified, and that *a new science of solid-state nuclear physics has been born*, although clearly with scant theoretical basis.

In electrolysis experiments, the Takahashi group uses several periodic modulation methods, achieving excess heat fairly consistently, and in some cases measuring low levels of nuclear reaction products. A low-high alternation of electrolysis current with a 12-hour period, or a saw-tooth ramp, or a six to eight step current-increase pattern are used in open electrolysis cells. The value of the deuterium loading factor is determined to lie between 0.8 and 0.95 in cases where excess heat is generated.

The Takahashi group also reported studies of thin (19 μm) foils of Pd loaded with deuterium from a 250 keV deuteron accelerator. To inhibit out-diffusion, the back side of the foil was coated with Ag (0-3 μm.) Si charged-particle detectors and a micro-channel plate were used to monitor emissions. Although most of the nuclear particles detected were products of deuteron-deuteron scattering, as expected, a small but statistically significant peak in the 3 to 5 MeV energy range lay beyond the 3 MeV cutoff of the deuteron-deuteron scattering products. Further experiments are proceeding, and various experimental parameters are varying.

Titanium is a good host for hydrogen (or deuterium), as well as being an abundant element. Several papers presented considered the possibility of cold fusion in Ti:D systems, in which loading factors up to 1.5 have been obtained. Jiroota, Kasagi [4] and coworkers at Tohoku University reported observations of high-energy protons emitted from Ti upon bombardment with a 150 keV deuterium beam. All protons with energy below about 9 MeV can be accounted for by the normal D(d,p)T reaction and "pileup" peaks related to this.

However, consistent appearance of a broad peak, 12.5 <Ep < 16.5 MeV, and occasional appearance of a sharp peak at Ep = 14.1 MeV were anomalous. The broad peak was interpreted as resulting from sequential reactions: D(d,^{3}He)n and D(^{3}He,p)^{4}He. The broadening is due to the isotropic distribution of the kinetic energy of the ^{3}He created in the first reaction, and its energy loss as it travels through the Ti metal. Calculation of the shape of the broad peak based on the sequential reaction model showed good agreement with the observed peak shape.

The sharp peak at 14.1 MeV is attributed to protons from ^{3}He(d,p)^{4}He, in which the ^{3}He is at rest after having been stopped in the Ti metal. This is considered important evidence that ^{3}He is accumulating in the Ti lattice because of the nuclear transmutation during the deuterium loading process. The sharp peak has appeared in only three of 50 experiments, a fact attributed to fluctuations in the structure of TiD_x consistent with the special conditions for nuclear-fusion reactions to occur. Thus the Tohoku group has joined the growing list of investigators who think they have evidence of cold fusion in the Ti:D system.

Presentations of countrywide reviews of cold-fusion research were given by Xing Zhong Li [5], Vladimir Tsarev [6] and Franco Scaramuzzi [7]. They summarized research in P. R. China, Russia and related countries, and Italy, respectively.

Although the number of locations in China that are involved in cold fusion research has been reduced in the past year, a strong and well coordinated research program continues. Li reported a neutron count rate of 8000/s reproducible for more than 18 months. He reported neutron activation experiments on In and Ir foils that give near theoretical lifetimes of 53 min and 19.6 hr, respectively. He reported observation of neutron energy spectra from Nb electrodes that had been loaded with deuterium, helium or hydrogen. The neutron emission count rates for the latter two gases was 100 times smaller than for Nb:D electrodes.

Li expressed the opinion that cold fusion has been confirmed. He concludes that Pd is not necessary, as witnessed by their Nb experiments, but that a film of some metal is necessary. Also, Li referred to the *new science of solid-state nuclear physics*!

A most entertaining and artistic review of research in the now fissioned CIS was given by Tsarev. He summarized 25 papers published in the former USSR during the past year, down from 80 the previous year.

The leading result from this group was Kabir Kaliev' [8] paper, "Reproducible Nuclear Reactions during Interaction of Deuterons with Oxidized Tungsten Bronze." Using Na_2WO_3 single crystals dosed with deuterium, Kaliev claims 100% reproducibility of neutron emission results in 93 experiments. With hydrogen dosing, no experiments gave neutron emission. Some, but not all experiments also produced increasing temperature. Photomicrographs of the Na_2WO_3 crystals showed parallel channels, which were effective diffusion paths for Li atoms. These experiments are currently being checked at Lebedev Institute in Moscow.

Another paper summarized by Tsarev claimed high excess-power generation in a deuterium glow discharge. The best result was 33 W, or 500% excess-power generation. Emission of slow neutrons, fast neutrons, charged particles, and acoustic waves were studied in other Russian experiments. Tsarev summarized that charged particles are 10^6 times more prevalent than neutrons in these experiments, but that 99.9% of the heat generation remains to be accounted for.

Tsarev recalled studies of years ago at Novosibirsk of LiD + D^2O, yielding LiOD + D_2 and weak neutron emission. These studies were confirmed by visiting scientists from Moscow, but never explained.

Scaramuzzi summarized ten papers from Italy. In a subterranean low-background laboratory, no neutron emission was detected from Pd electrodes used in electrolysis, or from deuterium loaded titanium. However, at Padua, 2.5 MeV neutrons were detected from deuterium-dosed Pd and Ti plates. These emissions were in the form of bursts of about 50 hr duration observed after 20 days of cell operation.

THEORIES

A great deal is known about the structure of hydrogen in Pd and other metals. In equilibrium in the Pd:D lattice, a phase of PdD forms in which the deuterium occupies octahedral sites about the Pd atom. The D-D distances are very large: 0.245 nm. Around a Pd vacancy, this distance shrinks to 0.185 nm, still very large compared with 0.074 nm of the deuterium molecule, in which fusion does not occur spontaneously, of course.

Yuh Fukai [9] reviewed the *AECs of the hydrogen-metal system* for the conference. If two deuterium nuclei were forced to approach each other against the repulsive force of the Coulomb barrier, Fukai asked, at what internuclear distance would the probability of a fusion reaction reach a reasonable level, say 10^{-20} per nucleus per second. Using standard nuclear reaction theory, he obtained the result 0.015 nm, or about a fifth of the equilibrium separation in molecular deuterium. If no screening is assumed, the repulsive Coulomb-barrier energy at that separation is 96 eV, which is much larger than might be provided by phonons or other normal types of lattice interactions.

Of course, screening of the Coulomb interaction must be considered. However, the conduction electron density available for screening the d-d interaction is much too low. The ten 4d electrons of Pd are in a closed-shell configuration, tightly bound to the Pd atom, according to accepted atomic theory. Thus, the density of electrons available for screening the d-d interaction, thereby reducing the strength of the repulsive Coulomb interaction, is completely inadequate. Hence, lattice forces available for squeezing deuterons together are one-hundred-fold too weak by accepted solid-state theory.

Among several attempts to explain cold fusion phenomena using solid-state physics concepts are the papers by Scott Chubb and Talbot Chubb of Research Systems, Inc, Arlington, VA. [10]. They conceptualize an ion band structure for the deuterium ions in the Pd metal, as has been hypothesized previously for hydrogen on metallic surfaces.

By applying the concepts of delocalized, periodic band-structure-type wave functions to the deuterium in the Pd metal, the Chubbs argue for deuterium nuclear reactions that are *not dominated by interactions between individual deuterons*. Invoking the indistinguishability of deuterons as in Einstein-Bose statistics, they argue that the Coulomb barrier that normally prevents two nuclei from approaching each other closely enough for fusion to take place does not prevent fusion of deuterons in the periodic potential of the Pd.

Perhaps the most serious attempt presented at the Nagoya conference for developing a physical theory that allows for significant nuclear-fusion reactions over interatomic distances in metals was presented by Peter Hagelstein of MIT [11]. Using two innovative concepts, Hagelstein calculated the probability of coherent transfer of a virtual neutron to the site of another, remote nucleus. Surprisingly, he found that coherent transfer of a virtual neutron should be possible to nuclei as far as one micron away in the periodic potential of the metal. He reported that Bragg scattering of the virtual neutron should be enhanced by 10^3 to 10^4. He used the Franck-Condon factor to couple nuclear energy with lattice energy via localized vibrational modes surrounding tetrahedral sites (not the normally occupied octahedral sites) in Pd:D.

Giuliano Preparata [12] described his quantum electrodynamical (QED) theory presented in 1989, which will be included in his forthcoming book on quantum electrodynamics in condensed matter. He argues that using QED to describe the screening interaction, the Pd 4d-electrons can be used to effect screening of deuterons as far as 0.7 nm from the Pd atom. In this case, fusion should occur at either tetrahedral or octahedral deuterium sites in Pd.

Jean Pierre Vigier [13] suggested using the quantum electrodynamical vacuum-fluctuation theory of Plutov to describe cold nuclear fusion. He looks for evidence of capillary conduction, which gives rise to Ampere's Law forces that break the capillary into beads. His theory predicts excess heat from electrolysis using H_2O as well as D_2O!

SUMMARY

Three and one-half years after the dramatic initial announcements, cold fusion remains a most highly controversial field of research. Most scientists would agree, probably, that each good research scientist possesses two vital characteristics: curiosity and skepticism. Both characteristics must be present and balanced for the research scientist to function efficiently.

No research exists without curiosity, and no science exists without skepticism. Yet we scientists are mortal human beings with human frailties and

inadequacies. We may neglect, or even purposefully ignore our philosophical principles in certain circumstances.

A scientist, without his natural curiosity, reacts with cynical rejection of any report that conflicts with his current understanding of nature. A scientist, without his natural skepticism, reacts with child-like gullibility to reports of wondrous new observations of nature. Both of these polarizing reactions are noncontributing embarrassments to the scientific community. Both of these extremes were apparent at Nagoya.

Cold fusion, as a field of research, has suffered (and perhaps also benefitted?) from the human lapses of its practitioners and its critics. Both positive and negative effects were abundantly evident at the Nagoya conference. The positive aspect was the stimulating atmosphere for those not so emotion-bound as to be unable to appreciate the humor of the scene, full-grown (yet immature) scientists making fools of themselves before their colleagues and the ubiquitous television cameras!

As a new field of research, cold fusion is more prone to polarizing reactions than other new fields that in recent years have been opened through dramatic discoveries. Experimentally it crosses interdisciplinary lines by involving such disparate fields as electrochemistry, nuclear physics, solid state physics, materials science, and others. Also, the data have been unusually difficult to control experimentally. This circumstance applies great stress on the most fundamental premise of physical science: the infinite reproducibility of experiment.

Theoretically, the explanations suggested by the curious scientists have stretched far beyond the experience of skeptics. This mix of reactions has been psychologically and socially explosive, producing the most deprecative public criticisms recorded by reputable scientists in this century. Clearly this outrageous behavior has not contributed to a dispassionate, scientific evaluation of research results.

A major psychological difficulty was the use of the term *cold fusion*, which invokes images of an inexhaustible source of cheap energy for society, and major deficiencies in current nuclear theory. A more appropriate term suggested at the conference was *anomalous nuclear reactions in condensed matter*. Although it may be too late to prevail upon the scientific community to switch terms, softening the expectations for cheap energy might reduce the emotional extremes and polarization of the scientific community.

Perhaps the clearest scientific fact, at this time, is the hardest for physicists to accept: nuclear reactions apparently do occur in deuterium-loaded Pd, Ti, and probably in other solids. The most exciting claim for technology and society, that of the availability of large quantities of thermal energy in simple electrolytic cells, is the claim that is least reproducible. Even this claim seems to be gaining credibility, although at reduced energy densities. The quantitative connection between the two remains problematic. That fact is a discouraging one for scientists.

For the progress of knowledge, and for assessing the potential technological and social impact of cold fusion, it is important to control reliably the generation of thermal power. Neither science nor technology can progress far without reliable, reproducible experiments. Researchers are working hard toward this goal, and some may have achieved it. It is clear that deuterium loading factors, and all the material parameters involved in that, need to be studied carefully along with schemes to minimize out-diffusion of deuterium.

Nondeuterium systems that have been reported to provide excess heat should be pursued vigorously, seeking the controllability and reproducibility necessary to convert these observations into acceptable scientific fact. Both Mahadova Srinivasan [14], Bom-bay, and Yamaguchi reported excess heat production in systems involving only ^{1}H. In Srinivasan's experiments, the excess heat generation was accompanied by detectable nuclear products, while Yamaguchi found no neutron or charged-particle emission accompanying excess-heat generation in hydrogen-loaded Pd MOS plates. If nuclear reactions occur in ^{1}H-loaded solids, mechanisms beyond those suggested by Hagelstein must be involved.

It seems important to remind ourselves that neither excess-heat generation nor solid-state nuclear events are observed in crystals of natural minerals, for example. If such reactions occur in crystals, which are loaded with ^{1}H or ^{2}H, there must be a trigger or control process that rarely functions in natural materials. On one hand we ask how solid-state nuclear reactions can occur. On the other hand, if we accept as fact that solid-state nuclear reactions do occur, we must ask why they are so rare in our Earth.

It has become clear that a more concerted theoretical effort is now justified to understand, first, whether the occurrence of nuclear-fusion reactions in solids can be justified within current basic

physical theory; and second, how the level of excess-power generation that has been reported might be rationalized with the low level of nuclear reaction products observed.

There is much research to be done before a clear understanding of the phenomena called *cold fusion* can be claimed. Now, it appears to be justifiably on scientific grounds to pursue this goal. Recent news reports in Japan suggest that MITI now concurs in this judgement. When the new budget is submitted to the Japanese Diet in early 1993, MITI's judgement will be apparent. MITI's Hydrogen Energy Study Group, a consortium of industrial researchers, is expected to pursue this subject vigorously. NTT has announced plans to follow up and expand the research results of Yarnaguchi and Nishioka. In all, in Japan, at least, US$10M per year will be spent on research in this field over the next few years.

Certainly China and probably Russia, India, and Italy plan to pursue research in the science of solid-state nuclear physics, and in its potential applications to energy technology, as well. In all, there is reason to believe that a clearer understanding of the science and technology of anomalous solid-state nuclear and spontaneous excess-heating phenomena will be forthcoming.

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1. Hideo Ikegami
National Institute for Fusion Science
Nagoya, 464-01, Japan
Phone: (011) 81-52-781-5124
FAX: (011) 81-52-789-1037
Email: ikegami@nifs.ac.jp

2. Eiichi Yamaguchi, or Takashi Nishioka
NTT Basic Research Laboratories
Musashino-shi
Tokyo, 180, Japan
Phone: (011) 81-422-59-2679
FAX: (011) 81-422-59-3591

3. Akito Takahashi, Toshiyuki Iida,
Takayuki Takeuchi,
Akimasa Mega, or S. Yoshida
Department of Nuclear Engineering
Osaka University
Yamadaoka 2-1
Suita, Osaka, 565, Japan
Phone: (011) 81--6-877--5111
ext 5081 or 5071
FAX (011) 81-6-877--3264

4. Jiroota Kasagi, Keizo Ishii,
M. Hiraga, or K. Yoshihara
Laboratory for Nuclear Science
Tohoku University
1-2-1 Mikamine
Sendai 982 Japan
Phone: (011) 81-22-245-2151
FAX: (011) 81-22-263-5358

5. Xing Zhong Li
Department of Physics
Tsinghua University
Beijing, 10084, P.R. China
Phone: (011) 86-1-259-4343
FAX: (011) 86-1-256-2768]

6. Vladimer A. Tsarev
...v. Lebedev Physical Institute,
Academy of Sciences
Department of Nuclear Physics
and Astrophysics
Leninsky Prospect, 53
117924, GSP, Moscow, Russia
Phone: (011) 95-135-87-28
FAX: (011) 95-938-22-51

7. Francesco Scaramuzzi
ENEA, Inn. SVIL
CRE ENEA I-00044 Frascotti, Italy
Phone: (011) 39-6-9400-5300
FAX: (011) 39-6-9400-5400

8. Kabir Kaliev
Institute of High-Temperature Electrochemistry
URAL Division, Academy of Sciences of Russia
S. Kovalevskaya
20 Ekaterinburg, 620219, Russia
Phone: (none given)
FAX: (none given)

9. Yuh Fukai
Faculty of Science and Engineering
Chuo University
1-13-27 Kasuga, Bunkyo-ku
Tokyo, 112, Japan
Phone: (011) 81-3-3813-4171

10. Scott R. Chubb & Talbot A. Chubb
Research Systems, Inc.
5023 No. 38th Street
Arlington, VA 22207
Phone: 1-202-767-5270
FAX: 1-202-767-5599

11. Peter L. Hagelstein
Research Laboratory for Electronics
Massachusetts Institute of Technology
77 Massachusetts Ave.
Cambridge, MA, 02139
Phone: 1-617-253-0899
FAX: 1-617-258-7864

12. Giuliano Preparata
Universita di Milano
Dipartimento de Fisica
Via Imerio 46
40126 Bologna, Italy
Phone: (011) 39-2-239-2242
FAX: (011) 39-2-239-2617

13. Jean Pierre Vigier
Laboratorie Physique Theorique
Tour 22, 4 Etage
Universite P. et M. Curie (Paris VI)
4 Place Jussier
Paris Ledex 75065 France
Phone: (011) 33-1-4427-4214
FAX: (011) 33-1-4051-0661

14. Mahadova Srinivasan
Head, Neutron Physics Division
Bhabha Atomic Research Center
Trombay, Bombay, 400-085, India
Phone: (011) 91-22-551-8845
FAX: 91-22-556-0750

Dr. Victor Rehn is currently a liaison scientist with the Office of Naval Research Asian Office in Tokyo. He assumed this position in May 1991. Since 1965 Dr. Rehn has been a research physicist with the Naval Weapons Center, China Lake, California. He started there as a research physicist in the Semiconductor Physics Branch, then as a supervisory research physicist he headed the Electron Structure of Solids Branch and the Semiconductor and Surface Science Branch, both in the Physics Division, Research Department. Dr. Rehn received his B.A. in physics at the University of California, Berkeley in 1953 and his Ph.D. in physics from the University of Pittsburgh in 1962. After completing his thesis research in nuclear quadrupole resonance studies of paradichlorobenzene and related materials, Dr. Rehn studied magneto-acoustic attenuation in metals at the University of Chicago. Upon moving to China Lake, he undertook research in electroreflectance of wide-gap semiconductors and insulators. Beginning in 1973, he participated in the establishment of the Stanford Synchrotron Radiation Laboratory and continued with the application of synchrotron radiation in research in semiconductors and semiconductor surfaces. In 1976 he initiated a research program in liquid-phase epitaxy, followed in 1984 by research in molecular-beam epitaxial growth and characterization of semiconductor materials and heterostructures. In 1987 he initiated research in the production of yttrium barium copper oxide superconductive thin films using excimer-laser ablation.

Dr. Iqubal Ahmad is the director of the Army Research Office (ARO) Far East. He has a Ph.D. in physical chemistry from Imperial College, London, and is a Fellow of the Royal Society of Chemistry, London. Prior to his present position, Dr. Ahmad was a program manager in the area of materials science at ARO, Research Triangle Park, North Carolina.

FREE-ELECTRON LASER RESEARCH IN ASIA

Research and development of free-electron lasers (FELs) is accelerating in Asia. Although Japanese, Chinese, Koreans and Russians were slow to follow the United States lead in FELs research a decade ago, now they all show great interest in this field of science. A high level of activity, considerable funding, and many innovative ideas are also being tried out in these countries. The major applications that are currently discussed in Asia include laser-fusion, nuclear-fuels reprocessing, medical science and surgery, materials science, and high-energy physics. Although there are currently no user facilities for FEL radiation in Asia, progress in the development of FELs suitable for user facilities is impressive.

Victor Rehn

INTRODUCTION

The 14th International Conference on Free-Electron Lasers (FEL '92), held in Kobe, Japan, 24-28 Aug 1992, highlighted the growth of interest in these unique light sources in Japan, China, and Korea. When compared to the research done a few years ago, the current level of related research activity in Japan, China, and Korea has grown very rapidly. Currently, I count about twenty active FEL hardware projects in Japan, two in China, and one in Korea. In addition to these, many other groups in all three countries are conducting related analyses or component development. While the level of FEL research in the United States is being leveled off by funding limitations, the much younger Asian efforts are expanding vigorously.

In this report, I summarize some of the Asian FEL research, both in FEL instrumentation and in scientific applications of FEL radiation. At the end of this article is a table of addresses and other contact information for readers who wish to make direct contact with personnel of the various Asian projects.

BACKGROUND

The FEL is the modern embodiment of the ubatron, an electron-beam driven microwave maser invented in 1958 by Dr. Robert M. Phillips, then at the General Electric Company Research Laboratory. Ubatron research was discontinued by 1965. In 1978 the FEL principles were discovered (or rediscovered) by J. M. J. Madey and coworkers at Stanford; therefore, FEL research has been vigorously pursued in the United States and Europe since that time.

This historical connection between the ubatron and the FEL was emphasized by the award of the 1992 FEL Prize to Robert M. Phillips. (Dr. Phillips is now at the Stanford Linear Accelerator Center, Stanford University, Stanford, CA, where he is again working on ubatron-related research after an interruption of nearly three decades.) It is generally acknowledged that John Madey's rediscovery was independent of Phillips' earlier work, coming instead from his quantum mechanical analysis of the interaction of photons with energetic electrons.

In the ubatron, the electromagnetic propagation velocity of the electromagnetic mode in the waveguide was matched to the electron velocity for maximum coherence and energy transfer. A magnetic perturbation of the electron motion was introduced as an energy coupling between the electron beam and the electromagnetic field. The dispersion of the propagation velocity provided the means of microwave frequency selection for a fixed electron beam velocity.

In its current forms, the FEL depends on a low-emittance and relativistic electron beam that is perturbed periodically along its path, and thereby

stimulated to emit electromagnetic (EM) radiation. Magnetic electrostatic, or electromagnetic perturbations have been used in various versions of the FEL. Up to this point, the FEL description includes undulatory (UR) and wiggler radiation (WR) from synchrotron radiation sources.

The distinguishing feature of FEL radiation is the coherence imposed by an optical resonator through which the electron beam passes at nearly the speed of light. As in other types of lasers, the FEL emission spectrum is very narrow, and very high power densities are possible. FEL radiation may be in the microwave, millimeter-wave, infrared, visible, ultraviolet, X-ray, or even gamma-ray spectrum, depending upon the design of the machine. The broad spectrum of possible operation makes FELs and their applications appear very different one from another.

Radiation from the existing FELs is of wavelengths as long as a millimeter waves or as short as 300 nm. Designs of future FELs would provide radiation in the soft X-ray spectral region. Using laser back-scattering techniques, radiation in the X-ray and gamma-ray spectral regions may be obtainable at high intensity. Because of the great amount of energy reservoir in the relativistic electron beam, extremely high intensity beams of tunable wavelength, coherent, picosecond-pulsed FEL radiation seem to be possible.

INSTRUMENTATION ADVANCES

When extremely high-intensity beams are envisioned, it is natural to ask what are the technological limitations on the energy density. One of the prime limitations on the beam-energy density for any kind of laser lies in the optical cavity. Mirror-damage limitations of laser cavities have been studied, however the FEL introduces a new source of damage.

Because the perturbation that induces the electron undulations responsible for the electromagnetic emission is usually far from sinusoidal spatially, intense, incoherent or partially coherent, harmonic-frequency synchrotron radiation is also emitted by the electron beam. Although the power density in the synchrotron radiation is lower than the fully coherent FEL radiation, its photon energy is higher, frequently above threshold for optical absorption in the mirror's dielectric coating.

This problem is exacerbated dramatically for FELs that are designed for use in the vacuum ultraviolet or soft X-ray spectral ranges, where even the fundamental photon energy lies beyond the threshold for absorption in known dielectrics.

Among the more exciting instrumentation ideas discussed at the FEL conference were techniques for removal of higher-harmonic radiation from the FEL beam. Especially for short-wavelength and high-power FELs, the survival of mirrors is a major problem.

N. A. Vinokurov, Budker Institute of Nuclear Physics, Russian Academy of Sciences, Siberian Branch, Novosibirsk, Russia, showed how the design of the perturbing magnetic field in the FEL undulatory has been modified so that higher harmonic synchrotron radiation is separated vertically from the fundamental mode FEL beam. Mirror life is extended considerably .

Some of the new instrumentation ideas in the FEL development are concerned with efficiency and energy conservation. These considerations are especially important in large installations such as the contemplated laser-fusion application. Even in smaller installations in which cw (non-pulsed continuous-wave) operation is desired, such as the compact, mm-wave FEL under construction by KAERI (the Korean Atomic Energy Research Institute), up to 99.5% of the electron-beam energy can be returned to the power supply. The overall efficiency and running-cost factors are greatly improved.

From KAERI, a group represented by Byung-Cheol Lee reported progress in construction of a 100 GHz cw FEL. A Cockroft-Walton 400 kV power source supplies a strong-focussing acceleration tube that is fed by a low-emittance thermionic electron gun. The permanent magnet undulatory floats electrically at +400 kV. After passing through the undulatory and generating the FEL radiation, the electron beam is decelerated to ground potential again, thereby returning 99.5% of its energy to the accelerator.

From KEK (Japan's High-Energy Physics Laboratory in Tsukuba), a group represented by Shigenori Hiramatsu, Toshiyuki Ozake and David Whittum reported progress in the construction of a two-beam FEL in which the modulation is produced by the betatron motion of the relativistic electrons travelling through an ion-channel laser. This FEL has no electrostatic or magnetic undulatory, but only the plasma column of the ion-channel laser. The laser uses a fast-wave resonance with the betatron motion of the relativistic electron beam in an

ion-focussing channel. More details are contained in Physics of Fluids B4 (1992), p 730.

To date, 9.4 GHz microwave amplification has been obtained by passing a pulsed 800 keV electron beam, peak current 800 A, through a column of laser-ionized diethylaniline in a waveguide of cross section 5.5 X 11 cm. Peak-power amplification from 18 kW to 20 MW was reported. Based on the encouraging results of 800 KeV operation and modelling results, a 1600 KeV electron beam has been developed, and lasing has been observed as well. Two problems were mentioned: poor frequency discrimination, and a large axial density gradient in the plasma density.

Another ingenious instrumentation concept is the circular wiggler under development by Takahide Mizuno, Tsutomu Ohshima and Hirobumi Saito at the Institute of Space and Astronautical Science, Kanagawa, Japan. This concept has been implemented for microwave and millimeter-wave FEL radiation, providing a relatively compact microwave FEL source.

In this device, an electron beam of energy less than 500 KeV travels in a circular path through the circular wiggler in which there is an azimuthally periodic magnetic field. The resultant microwave energy is in a transverse-magnetic coaxial waveguide mode. The electron beam is mildly relativistic, $\leq$ 500 keV with 100 A peak current in an 6 μs pulse. The FEL is tunable over the ranges 11-14 GHz in the lower mode, and 19-38 GHz in the upper mode. The power levels achieved to date are 130 KW at 11.5 GHz, and 3 KW at 27 GHz.

At the design and concept stages, other exciting instrumentation ideas were discussed. Hiroshi Tsutsui, and Hironari Yamada, Quantum-Technology Section, Sumitomo Heavy Industries, Tokyo, collaborating with Kunioki Mima of the Institute for Laser Engineering, Osaka University, represented a project for the computer simulation of a photon storage ring. This device is comprised of an electron storage ring in which the orbit is an exact circle, and a concentric circular millimeter-wave resonator. The simulation was assumed 1-mm FEL radiation.

Two designs were considered: a 1-m diameter synchrotron orbit of energy 515 MeV, and a 30-cm diameter orbit of energy 50 MeV. The millimeter wave resonator operates in a transverse electric mode, for which gain was predicted by the simplified model.

The conceptual analyses of FELs from submillimeter waves to X ray was reported by H. Ishizuka, Fukuoka Institute of Technology, representing a group that included members from Saitama University and the Japan Atomic Energy Research Institute (JAERI).

In the case of X-ray FELs, they considered exploiting the Cerenkov effect in a crystal by using an array of very small, 10 MeV electron beams, 10 nm diameter, 1 μA current per beam. The crystal lattice provides the periodic potential for undulating the electron orbits, and X-ray FEL radiation should result according to the concept. The array of electron beams would come from an array of field-emission tips, as has been used in electron microscopes. Pulsed operation would mitigate the thermal limitations. Their analysis shows that the required beam parameters are achievable.

Another version of electrostatic FEL was discussed by a group of eight authors from five Japanese institutions. The electrostatic field is supplied by an array of needle-shaped electric poles placed on a rectangular plate. The interpolar spacing may be submillimeter, and electric fields may be as high as 800 kV/cm. A variety of operational modes were discussed. Claimed merits include ease of construction, short and tunable wavelengths, lower electron-beam energy, smaller space, and lower cost!

Yasuo Suzuki, representing the undulatory group of the FEL laboratory, JAERI, discussed micro-pitched plasma-undulatory concepts. Using an array of hundreds of slender plasma discharges, either electrostatic or magnetic forces can be used for undulating the relativistic electron beam. The magnetic-field-induced undulations are generated by passing electric currents through the plasma columns. Alternatively, beam undulations may be produced by the periodic electrostatic field that accompanies the plasma-density modulations.

An advantage of this concept lies in the ability to increase the *magnet gap* of the undulatory without diminishing the undulation force on the electron beam. It is predicted that the effect of collisions of the electron beam with plasma particles should be negligible.

S. A. Lutsenko and Nicholay A. Vinokurov, Budker Institute of Nuclear Physics, Novosibirsk, Russia, described their concept of a waveguide lens, a focussing device comprising a specially shaped waveguide. This device would be useful for focussing radiation into small-gap devices like compact

undulators, for example. Simulation and optimization calculation results were reported.

APPLICATIONS

In the application of the FEL to the study of living tissue, the problem of beam damage to the specimen has impeded progress. I was intrigued by a theoretical analysis of this problem by Claudio Pellegrini, now of UCLA. Pellegrini examined the possibility of producing an FEL-beam pulse of such high intensity and short duration that a complete soft X-ray microscopic image of a target specimen can be obtained within a single 0.2 ps pulse! Such a capability would allow the structure of organic or biological specimens to be determined so fast that the radiation damage caused by the FEL beam would not have time to alter the structure.

Pellegrini assumes a requirement for producing 10^{14} photons/pulse, pulse width $\leq$ 1 ps. He reported estimates that an electron beam of energy 5-10 GeV passing through a long FEL undulatory would meet the requirements. The FEL beam would have a spectroscopic resolving power of 500-1000, and the pulse width would be 0.2 ps.

Of the three large synchrotron-radiation storage rings currently under construction {the 6 GeV ESRF (European Synchrotron-Radiation Facility), Grenoble, France, the 7-GeV APS (Advanced Photon Source), Argonne, IL, and Spring-8, the 8 GeV Japanese synchrotron-radiation storage ring, Harima Science Park City}, none have a short enough pulse for this application. However, according to Pellegrini, a suitable linear accelerator could be built.

At JAERI, a FEL based on a superconducting linear accelerator is being built as a possible nuclear fuel reprocessing facility. In collaboration with N. Kikuzawa, Kyushu University, and J. Sasabe, Hamamatsu Photonics Co., the JAERI-Tokai group reported test results of superconductive cavity modules, built by Siemens AG following the design of the cavities used at Deutsche Electronen Synkrotron (DESY), Hamburg, Germany.

Professor Chiyoe Yamanaka's group, Institute of Laser Technology, collaborating with a group from the Institute for Laser Engineering, Osaka University, have proposed driving inertial fusion energy sources with FEL-pumped solid-state lasers. A 3-D FEL model has been used to determine the energy-extraction efficiency, gain and other parameters of the system, and complete the conceptual design.

SUMMARY

It is clear that FEL instrument designers are awash with innovative ideas, but ideas for applications were not abundant at FEL '92. There are competing techniques (e. g., synchrotron-radiation) for many applications, for which the FEL may be marginally superior. What seems to be lacking is a unique application for which there are no competing techniques, or none that come close to the same level of achievement. Applications requiring the greatest available beam-energy density or laser coherence in short-wavelength spectral regions would be candidates.

I have not reviewed the several operating FEL user-type facilities around the world (none yet in Asia). These include the superconducting linac FEL at Stanford, the far infrared van de Graff based FEL at the University of California, Santa Barbara, John Madey's Mark III rf-linac FEL at Duke University, the Vanderbilt University rf-linac-based FEL (a copy of Madey's FEL), the FELIX dual rf-linac driven infrared FEL at the FOM-Instituut voor Plasmafysica 'Rijnhuizen', Nieuwegein, Netherlands, and others that are less well developed as user facilities. Productive scientific experiments are being conducted at these and other facilities, and I would not suggest that such facilities are unworthy, scientifically or financially.

Several medical applications have been discussed, such as narrow-kerf, controlled-depth bone cutting, ophthalmological surgery, bloodless surgery, and spectroscopically selective cell destruction. Most of these applications can also be accomplished with other types of lasers, or with synchrotron-radiation sources. In materials science, surface and bulk phenomena have been investigated with FEL beams, but most of these applications could be accomplished with other methods, including synchrotron radiation techniques. I have heard of few unique applications of FEL beams in medicine or materials science.

In some spectral regions, such as the far infrared or the gamma-ray region, the FEL offers a clearly unique source with an extremely intense beam of highly coherent radiation. Both Shigenori Hiramatsu of KEK and Andrew Sessler of LBL discussed high-energy physics applications. Sessler's suggestion was for a gamma-gamma collider facility that he estimates to be feasible, and would seem to be a unique application of the FEL technology.

The unique qualities of FELs are the coherence and the extremely high-beam energy density. These qualities bring to the far infrared and hard X-ray spectral regions the same energy density as is available in the more accessible spectral regions with more customary laser sources. As scientists reflect on these unique features, possibly new, unique applications of FEL beams will appear. In the meantime, much good science can be done by using FELs. That fact should not be deprecated because of the availability of alternative types of facilities available to the experimenter.

SCIENCE AND TECHNOLOGY IN CHINA: IMPRESSIONS FROM RECENT VISITS

Roland E. Allen and Wiley P. Kirk

BACKGROUND

China has undergone substantial changes in the past three years—economically, scientifically, and even politically. People who visited only a few years ago are surprised by all the new buildings— some of them incredibly lavish—and by the openness to foreign visitors and business. Beijing, in particular, is now a very cosmopolitan city, with a tremendous concentration of wealth in some areas.

On the average, however, China is still a poor country. Also, one still encounters communist propaganda, even in the books on ancient history at the museums. The current trend is toward a market economy and away from central planning. Strong efforts are being made to attract foreign investment, and equally strong efforts are being made to promote applied science and technology.

Just by following the headlines of the *China Daily*, an English-language newspaper published by the government-owned China Airlines, one becomes aware of the current economic environment in China and its struggle for change.

China's national reform and opening policy, which got a boost from Deng Xiaoping earlier this year, is surging across the country.

Province by province seems to have been targeted for technological and economic development. Shaanxi Province in Northwest China is building a number of high-tech development zones in Xi'an, capital of the province, and Xianyang, Baoji, Weinan, and Yangling. The Xi'an high-tech development zone has approved establishing 144 Chinese and foreign-funded enterprises involving a total investment of 846 million yuan (US$157M). Construction of an electronics town with a total population of 100,000 is approaching completion in the southern suburban area of Xi'an."

Recent events also symbolize the changes in China: The Ministry of Culture announced some reforms that reflect a more liberal attitude toward the arts; there was a frenzy among applicants for new shares offered by the Shenzhen Stock Exchange; and billboards proclaim that 1992 is the "golden year" for travel in China. Only three other countries claimed more gold medals than China in the 1992 Olympics, and China is the leading candidate to host the Olympics in the year 2000.

Also, China recently launched a telecommunications satellite, in collaboration with the United States and Australia. The Associated Press reported that financial rewards—ranging from $18 per month bonuses to $200,000+ cash awards—are being presented to scientists and inventors who make contributions of exceptional practical value. A new slogan for China is attributed to Deng Xiaoping: "Science and technology are the number one productive force."

CONDENSED MATTER AND SEMICONDUCTOR RESEARCH IN BEIJING

Professor Sousheng Yan of the Peking University invited Wiley P. Kirk to present a series of lectures at the Beijing Summer School on Mesoscopic Physics. Other visiting lecturers at the summer school included Professor Johan Mooij, Delft University of Technology; Professor Poul Lindelof, University of Copenhagen; Professor Robert Silsbee, Cornell University; and Dr. Michael Roukes, Bellcore. The people attending these lectures in May 1992 came from various parts of China, some traveling as far as 500 km.

The guest lecturers had the opportunity to visit a variety of research laboratories in the Department of Physics at the Peking University, the National Laboratory for Superlattices and Microstructures at the Institute of Semiconductors of Academia Sinica (Chinese Academy of Sciences), and the Institute of Physics of Academia Sinica. In addition to the professional agenda, they were given several cultural tours around Beijing and its vicinity. These visits,

receptions, open discussion periods with students and faculty, and a dinner with upper administrative officials of the Peking University provided opportunities to probe into the characteristics of the Chinese scientific establishment. This establishment turns out to be surprisingly intricate, resourceful, and more aware of current worldwide research problems than most Westerners tend to realize.

Although Shanghai, Xi'an, and Hefei are all moving forward, the leading research institutions are still in Beijing. The top university in the country is Peking University, and the top facility for semiconductor research is the Institute of Semiconductors. These institutions, as well as the Institute of Physics and several other leading universities, are located in the same general area of Beijing, some distance from Tiananmen Square and the Forbidden City.

An official ranking of the various laboratories involved in semiconductor research actually exists, and the National Laboratory for Superlattices and Microstructures ranks No. 1. This laboratory maintains active collaboration with prominent semiconductor scientists in the United States and Europe. Scientists from overseas are officially welcomed. The director is Professor Hou-Zhi Zheng, and the international advisor is L.L. Chang (IBM). The equipment in this laboratory is impressive; it includes a VG-R80-MK 2 MBE growth system, various superconducting magnets, lasers; a JY-T800 Raman spectrometer, various instruments for photoreflectance, photocurrent, and photovoltaic measurements, and a VAX 3500 computer. Within this national laboratory there are specialty laboratories: Raman spectroscopy/photoluminescence (pressure) laboratory; modulation/infrared spectroscopy laboratory; time-resolved spectroscopy laboratory; deep level laboratory; cyclotron resonance spectroscopy laboratory; magneto-spectroscopy transport laboratory; and MBE materials laboratory. Experiments are performed down to 4.2 K, using liquid helium.

The National Laboratory for Superlattices and Microstructures is one of four laboratories organized within the Institute of Semiconductors, and one of 115 throughout China. Of these 115, 15 are ranked and regarded as being in a position of leadership. For example, the National Integrated Optoelectronics Laboratory at the Institute of Semiconductors is ranked No. 10. Most of the equipment in these laboratories is new, and much of it was purchased within the last few years. The Institute of Semiconductors has six MBE machines, four manufactured in China and two imported from the West (one costing US$1.8M). Besides MBE growth, other techniques are used, including MOCVD. Systems being studied include GaAlAs/GaAs quantum well lasers grown on Si, GeSi/Si, AlSb/GaSb/InAs, InGaAs/GaAs, and InGaAsP. The EL2 and DX traps in GaAs are being investigated. Many other topics currently being studied in the West are also under consideration at the Institute of Semiconductors.

It is evident that the scientists in the better labs are intelligent and hardworking, and are also capable of hands-on experimental work. The research in these laboratories is strongly supported by the Chinese government. The best work appears in standard American and European journals, such as the Physical Review. One expects that the semiconductor laboratories in Beijing and other parts of China will be producing world-class research in the near future.

To an outsider, China's most striking feature is that it is a land of contrasts. It is common to see horse drawn carts and bicyclists hauling coal and traveling alongside vehicular traffic moving at 50 km/hr. There are many scenes of large road crews working with wheel-barrows and shovels alongside modern concrete mixers. At the universities and technical institutes, farmers and produce vendors of every sort congregate around the gates selling everything from raw meat and vegetables to cobbled shoes. Yet, inside these campuses one sees laboratories featuring some of the latest scientific equipment from Europe, Japan, and the United States. China, unlike many third world countries, is both poor and rich.

In visiting the research laboratories, one is somewhat overwhelmed by the large size of the departments. The Department of Physics at Peking University has more than a thousand students, faculty, and staff! Also surprising is the fact that the buildings and physical facilities are rather poorly maintained. Most lighting in the hallways has been removed or is kept turned off to conserve energy. Objects of all sorts, such as ankle-height metal plates and old equipment, appear to be abandoned in these dark hallways. The countless breaches of safety standards would keep an agency like OSHA busy for years!

Besides the inattention to safety, there is an absence of high quality infrastructure, such as machine and electronic shops. Some programs suffer because of a lack of adequate cryogenic facilities. For example, we saw several cryostat stations in limited use, and one large Oxford Instruments

dilution refrigerator had not been operated for well over a year because liquid helium was scarce.

Although the physical facilities are less than optimal, this does not impede the researchers from tackling first rate problems. The Chinese display enormous resourcefulness and patience in their research. First, they have a good understanding of the scientific problems they are working on; they select only the essential tools and items of equipment needed to investigate a particular problem. Second, they are acutely aware of the level of activity in Western science, and they study and observe this activity closely. They know what works, and thus avoid wasting time and resources on exploratory efforts. Almost every laboratory has at least one experienced, senior researcher who has traveled abroad and worked for periods of months to years in first rate laboratories within Europe, the United States, and Japan.

These individuals are respected by their peers and are expected to set the standards. They know precisely what equipment and problems to focus on. Fine work is consequently being produced in several areas: polymer surface chemistry using STMs; liquid phase epitaxial growth of multi quantum well structures for electro-optic materials; MBE growth of a variety of II-VI and III-V compound semiconductors (including growth of GaAs on (110) nearly six years before it was done in the West, using in this case a Chinese built MBE machine designed mostly after a Vacuum Generators Instrument); electron-beam patterning and processing of 0.1 μm features on silicon; and laser ablated growth of high-quality thin film high T_c superconductors. Also gas-source epitaxy is being developed, but this appears to be conducted with less than optimal attention to proper safety procedures for handling the extremely toxic materials. Accompanying these many well thought-out scientific studies were a large array of analytical instruments for sample characterization and surface analysis, such as SIMS, Auger, ESCA,photoluminescence, and Raman spectroscopy. Almost all of this equipment was purchased in the West.

Two points should be noted about future opportunities for students who are trained in the West and then return to China. First, very few Chinese students have actually returned at this point. Most of those who left China to attend graduate school elsewhere are still in holding patterns in the United States and Europe. Second, there are a few success stories: A few young scientists who received their Ph.D.s outside of China (mainly in Europe or Japan rather than the United States) have returned to promising careers. These people seem to be genuinely happy, and apparently returned because of a combination of family considerations and good jobs (e.g., at the Institute of Semiconductors). If more resources continue to be provided for scientific research, more young scientists may return to China from the West.

SUMMER CONFERENCES IN CHINA ADDRESSING SEMICONDUCTOR RESEARCH

21st International Conference on the Physics of Semiconductors

Roland E. Allen participated in the 21st International Conference on the Physics of Semiconductors (ICPS-21), held August 10-14, 1992, in Beijing. The organizer of this conference was Professor Xide Xie, formerly President of Fudan University in Shanghai. After surviving the Cultural Revolution, she went on to become influential in Chinese politics, and she has had a very positive effect in promoting semiconductor physics. Her proposal to hold ICPS-21 in Beijing was accepted by the ICPS committee in 1988. In 1990, after the tragic events of Tiananmen Square, almost half the ICPS-20 participants (in Thessaloniki, Greece) signed a petition against the Beijing site. It was reconfirmed by only a very narrow vote. If anyone other than Professor Xie had been the organizer, the vote would probably have gone the other way.

Many scientists in the West faced a difficult decision in determining whether to attend this conference. A few actively boycotted it (including several eminent physicists associated with the Max Planck Institute in Stuttgart). Others made a point of coming, in order to show support for their Chinese colleagues. About five hundred scientists from outside China attended, which is probably not much lower than the number that would have come without political complications.

Several speakers at the conference said a few words in support of political prisoners (and mentioned Chinese scientists in the West who were afraid to return for the conference). A petition was circulated on behalf of one prisoner who has received particularly brutal treatment.

There were several good plenary talks at the conference: H. Stormer, AT&T Bell Laboratories, spoke on the fractional quantum Hall effect, and the

anticipated transition to a Wigner lattice. He concluded that a number of issues are still unresolved: (1) Primitive odd-denominator fractions, like 1/3, 2/3, 1/5, and 4/5, are well understood, and the Laughlin wavefunction provides a good description. However, the hierarchy of more complex fractions is still poorly understood. (2) Even-denominator fractions, like 5/2 and 7/2, are not well explained theoretically. (3) The existence of the Wigner solid is still ambiguous. V.J. Goldman of Stony Brook spoke on single-electron tunneling, the Coulomb blockade, and double-barrier resonant tunneling structures. (He replaced D.V. Averin of Stony Brook and Moscow State University,) M. Scheffler, of the Fritz Haber Institute, spoke on defects in GaAs and $Al_xGa_{1-x}As$: EL2 is related to As_{Ga}, and the DX center is related to a group IV element on the Ga site or a group VI element on the As site. The metastability of these defects is a clue to their nature. The basic picture of the DX defect provided by Chadi and Chang in 1988 appears to be holding up. D.J. Wolford of IBM-Yorktown Heights presented a very interesting talk on the behavior of semiconductor band edges, shallow and deep impurity levels, and heterojunction band offsets under pressure. Old assignments of band positions, and old data on pressure dependences, have been corrected. Predictions of tight-binding theory appear to be correct.

On Wednesday morning, D. Bürgler of the University of Basel spoke on studies with scanning tunneling microscopy, atomic force microscopy, and other members of the "SXM" family. (He replaced H.I. Guntherodt, who had just been elected president of this university.) On Friday, P. Voisin of Ecole Normale spoke on Wannier-Stark effects in semiconductor superlattices. The topics discussed—Bloch oscillations, Franz-Keldysh oscillations, etc.—were among the highlights of both this conference and the one in Xi'an.

Many other interesting presentations were made over the five days of the conference. During this period, R.E. Allen gave a talk, presented two posters, chaired a session, visited the Institute of Semiconductors, toured the Peking University campus, and attended as many talks as possible. The proceedings of ICPS-21 should be published in about a year.

Here are some representative talks at ICPS-21 from Chinese institutions: T.H. Wang, X.B. Mei, C. Jiang, Y. Huang, and J.M. Zhou (Institute of Physics, Beijing), used time-resolved and time-integrated photoluminescence to investigate nonresonant electron tunneling between asymmetric double wells. They concluded that LO-phonon-assisted tunneling is the dominant process. There was a theory talk on CdSe/ZnTe interface phonons by Y. Jin et al., of Peking University and the Shanghai Institute of Technical Physics. S. Yuan, J. Li, and Z. Peng, of the Shanghai Institute of Technical Physics, used various optical techniques to study short period superlattice quantum wells of ZnSe, ZnTe, CdSe, and CdTe. M. Zhang, G.S. Dong, Z.S. Li, X. Jin, and X. Wang of the Surface Physics Laboratory, Fudan University, in an invited talk reported a semiconductor-metal phase transition at the Mn/GaAs (100) interface. W. Yang, J. Jia, and R. Zhao, of the Peking University, described an EELS and AES investigation of the reaction of Pb with Si(111) and Si(100) surfaces. J. Shen, G. Zheng, S. Guo, and D. Tang, of the Shanghai Institute of Technical Physics, studied resonant-acceptor-bound magnetic polarons in Hg0.97 Mn0.33Te. P. Han et al., of the Nanjing University, grew and characterized strain-relaxed Si1-xGex layers on Si(100). In an invited talk, S.L. Lei of the Chinese Center of Advanced Science and Technology, Beijing, and the Shanghai Institute of Metallurgy, discussed Bloch miniband transport in semiconductor superlattices. Z.X. Zhao, Chinese Academy of Sciences, gave a plenary talk on high-temperature superconductivity. K. Chen, J. Xu, X. Huang, and D. Feng, of the Nanjing University, reported photoluminescence measurements showing visible light emission from crystallized a-Si:H quantum wells. X. Lu, X. Hou, X. Ding, and X. Wang, of the Surface Physics Laboratory, Fudan University, used HREELS to study reaction products during V/III-V and III/III-V interface formation. In an invited talk, G.G. Qin, of the Peking University, described control of hydrogen-containing Schottky barriers through biased annealing. Finally, H. Tian, B.J. Yang, and X.W. Fan, of the Changchun Institute of Physics, reported studies of the lasing properties of ZnSe films grown with VPE and OMVPE.

6th International Conference on Superlattices, Microstructures, and Microdevices

R.E. Allen participated in the 6th International Conference on Superlattices, Microstructures, and Microdevices (ICSMM-6), held August 4-7, 1992, at Xi'an Jiaotong University.

The first, and perhaps most interesting talk, was given by A.V. Nurmikko, Brown University, about Blue-green lasers and blue, green, and yellow LEDs have been fabricated with ZnSe-based quantum well structures, involving (Zn,Cd)Se/Zn(S,Se). There are still problems with contact/heterojunction heating and materials stability, but useful devices may be feasible in several years. There were a number of other stimulating presentations concerning miniband transport, Stark ladders, and Bloch oscillations. The field covered by this conference has blossomed during the past several years, and one can foresee many new applications in electronics and optoelectronics. The proceedings will appear in forthcoming issues of *Superlattices and Microstructures.*

As mentioned above, Xi'an is projected to become a technology center. Already there is a modest amount of semiconductor research at Xi'an Jiaotong University where ICSMM-6 was held. ("Jiaotong" literally means "traffic," but no one seemed to know the history of this name. It probably has something to do with the strong orientation of this university toward engineering.) Of the 1075 universities in China, ten are listed for priority construction, and this university is one of those ten. It is also one of the two oldest universities in China; it was founded in Shanghai in 1896 and moved to Xi'an in 1956. It has 9000 undergraduate students, 2000 graduate students, and 2000 full-time teachers. The beautiful conference center which housed ICSMM-6 is another symbol of China's recent progress. It was finished in April, 1991. All the poster stands were constructed by Xi'an University students only one month before the conference!

There was one political problem at this conference. Since it was sponsored by the Chinese Academy of Sciences, and since "Taiwan" was changed to "Taiwan, China" whenever it occurred in addresses on abstracts, the government of Taiwan would not let its scientists attend. This problem did not arise at ICPS-21, which had different sponsorship and *was* attended by scientists from Taiwan. It is interesting in this context that China now receives about one million visitors from Taiwan each year.

TRAVELING IN CHINA

Travel to Beijing by air is easy, and one can live economically in very luxurious hotels (or in adequate housing provided by universities and institutes). Difficulties arise only when one tries to travel to other locations within China. The Chinese airlines now operate modern planes that are safe and comfortable, but their schedules are still erratic. One can easily arrive a day or more behind schedule because of weather, equipment, personnel, or other random problems. The Chinese tourist agency (CITS), which was involved in arranging both ICPS-21 and ICSMM-6, is rather unreliable. Sometimes its people operate with remarkable precision and efficiency, and at other times they are capable of mind-boggling incompetence.

The alternatives to flying, however, can be even more difficult. Train tickets must be purchased well in advance, and driving is ordinarily not an option.

CONCLUSION

One quickly realizes that China is making rapid progress economically and scientifically. It may be appropriate to close with a final indicator: Before 1989, China exported no computers to the United States. Now, China's share of the U.S. computer market is 4.3%.

Dr. Roland E. Allen received his B.A. in Physics from Rice University in 1963, and later his Ph.D. in 1968 from the University of Texas at Austin.

After being at the Argonne National Laboratory, in 1969, for a year as a Resident Associate, Dr. Allen moved to Texas A&M University where he still resides as a Professor of Physics. In 1980, Dr. Allen interrupted his presence at the Texas University by going to the Solar Energy Research Institute as a Sabbatical Scientist for a year.

Dr. Allen is currently interested in Theoretical Solid-State and Surface Physics research. He has been prolific both in the publication of numerous papers in scientific journals, and in presentations at various colloquia, talks, seminars, and workshops.

Dr. Allen has been the organizer of several workshops on "Theory and Modeling for Materials Design," and on "Surface Dynamics".

Dr. Allen is a member of the Editorial Board for "Superlattices and Microstructures" and a member of the "American Physical Society," the "American Vacuum Society," "Materials Research Society," and the "American Association for the Advancement of Science".

Dr. Wiley Price Kirk received his B.A. in physics in 1964 from Wahirgton University, St. Louis; his M.S. in 1967 and his Ph.D. in 1970 from State University of New York at Stony Brook.

Dr. Kirk, after being an Assistant Professor at the University of Florida from 1970, moved, in 1975, to Texas A&M University in the capacity of Professor of Physics and Electrical Engineering. At present he is also Director, Center for Nanostructure Materials and Quantum Device Fabrication, TAMU.

Dr. Kirk is extensively experienced in a vast variety of scientific areas, such as experimental condensed-matter physics and related topics. He established a University Center for Nanoscale Science and Technology, which involves electron-beam patterning and molecular epitaxial growth of artificially tailored materials. Dr. Kirk has had books published on the subject of physics, and holds a pattern "Gate Adjusted Resonant Tunnel Diode Device and Method of Manufature.

Dr. Kirk has published a number of papers, five of which are closely related to Project. He has been awarded the Brookhaven National Laboratory Summer Fellowship in 1967, the NSF Postdoctoral Fellowship in 1970-72, the National Bureau of Standards Precision Measurements Award in 1987, and the TEES Research Fellow in 1992.

ADVANCES IN HIGH-STRENGTH FERROUS ALLOYS

INDO-U.S. PACIFIC RIM WORKSHOP 25-29 MARCH 1992

Work reported at the ARO-FE/ONR/NML cosponsored workshop held at Delhi, is briefly reviewed.

Iqbal Ahmad

INTRODUCTION

Historically the high-strength ferrous alloys are based on the Fe and C systems with substitutional and interstitial element additions and a variety of ingenious thermomechanical treatments to achieve desired properties with minimum sacrifice of the toughness and corrosion resistance. However, this approach has always led to cost penalties in the form of low weldability and difficulties in fabrication. In recent years, new compositions with low-carbon contents have been developed and commercialized. Today carbon is increasingly being viewed as an impurity in structural steels and in this regard is almost in the same category as sulphur, phosphorus, hydrogen and nitrogen.

To achieve improved strength (80-100 ksi range) combined with improved fracture toughness, judicious additions of refractory metals in small amounts combined with new thermomechanical treatments have been adopted. However, very high-strength (100-300 ksi range) steels are being designed from the first principles and experimentally investigated with good results (for example at the Northwestern University, U.S.A.). A worldwide research activity is being done on the improvement of the mechanical properties of steel products at the lab scale and their processing at industrial scale. Some new thermomechanical treatments such as variations of controlled rolling and accelerated cooling have been developed in many countries such as Japan, Korea, Australia, and India.

To review the progress and discuss the ongoing work in the area of improving the strength-fracture, toughness stress, corrosion resistance, weldability properties of advanced ferrous alloys, particularly in the Pacific Rim Countries, the Army Research Office-Far East, ONR, and the National Metallurgical Laboratories, Jamshedpore India, cosponsored a workshop at the Maurya Hotel, Delhi, on 25-29 March 1992. An important objective of the workshop was to bring together active workers in the region with the intent of fostering international collaboration, and to identify direction of future research.

WORKSHOP SUMMARY

The workshop was formally opened by Dr. Rama Rao, Secretary for Science and Technology, India. This was followed by a formal welcome messages on behalf of the ONR, ARO, and NML respectively by Dr. B. Rath, Associate Director NRL, Dr. I. Ahmad ARO-FE, and Dr. A. Mohanty, Deputy Director of the National Metallurgical Laboratories Jamshedpore, who was also the cochairman of the workshop. The workshop consisted of six sessions:

1. Steel activity in Pacific RIM countries-A perspective view.
2. Phase transformation and strengthening mechanisms.
3. Structure-property correlation.

4. Thermomechanical processing and intercritical treatment.
5. Application areas of low carbon ferrous alloys.
6. Fluid flow and welding.

At the end of the workshop a panel discussion was held. The proceedings of the workshop will be published in the form of a monograph. The following are summarized selected highlights of the work reported.

Of the Pacific Rim countries, Japan is the largest producer of steel, Korea follows, then India and Australia. As a result of a number of economic factors including the oil crisis, the production of steel in Japan declined in the 1985-88 time frame. In 1986, the production of crude steel was 96.4 million tons of which Japan exported 31.5 million tons. Japanese profits in the steel industry dropped dramatically. At that time industrial leaders forecast that the export of steel would continue to decrease. To cope with this, the steel industry adopted important restructuring measures, which included planned reduction in production capacity, reduction in labor force (Japanese style), reduction in unit production cost by introducing advanced technology including energy saving and automation, and increased production of high value added products. Also, serious consideration was given to the existing coking ovens, which had only limited life left (most of the existing ovens have useful life up to year 2000). Therefore, a choice had to be made in planning the future blast furnaces. The Japanese industry is presently considering replacing blast furnaces with newer technologies that include direct reduction processes. The restructuring approaches have been proven successful. The Japanese unit consumption of energy is now 100 against 140 in the United States, 126 in Italy, 117 in the UK, 111 in Germany, 115 in France, and 117 in Brazil. The shift to value added products has dramatically influenced the trends of the steel technology. For example the demand for the surface treated sheet steel in the automobile industry and the TMCP (thermo-mechanical controlled process) steel in the field of construction, pipeline, marine structures, and ship building has increased. This gave added support to the introduction of new technologies such as refining, continuous casting, hot rolling. The whole process was facilitated by the availability of low-interest-rate capital for new investments, by the industry. Dr. Tsukada of the NKK corporation elaborated on the use of the technology of controlled rolling followed by the accelerated cooling. He stated that this technology had been completely developed in Japan in 1985. Almost 2.7 million tons of TMCP steel (accelerated cooling type) is presently used in the ship-building industry. In the area of research more than 40 papers on accelerated cooling are presented annually at the Iron and Steel Institute, Japan. Innovations in technologies necessary for the production of high quality steel have focussed on desiliconization, dephosphorization, and desulphorization in the pretreatment processes of hot metal. Other technologies downstream include degassing and reduction of shape control of inclusions. Introduction of bottom blowing and DC Arc electric furnace further contributed to improvement in quality and energy saving. The continuous casting rate in Japan is considered to be the highest in the world. The latest slab casters are capable of casting 360,000 tons per month per caster. Recently, efforts have been made for linking continuous casters with hot rolling process, so as to use sensible heat energy contained in the slabs.

Korea is one of the major steel producing countries. Its consumption of steel has increased from 2 million tons in 1960 to 20 million tons in 1991. Professor Young Gill Kim, reviewing the status of the steel activity in the country, stated that at the Pohang Steel mill there are three blast furnaces and the fourth was being added. The plant at the Kwanyang is producing 9.4 million tons of stainless steel products. In the automobile sector extra low carbon ferritic steels are being used. They include Al-killed (DDQ) and Ti-P (DQ). Further research is in progress for developing new austenitic grades for automotive applications. Most of the research in the ferrous metallurgy is product and process oriented and is being conducted at POSTECH and RIST. RIST, the Research Institute of Steel Technology is fully supported by the Pohang Steel plant. POSTECH is the teaching institution that along with POHANG and RIST form a trio, a major Korean center for the research on advanced steel metallurgy and new materials. RIST and POSTECH are only a few years old and are making very fast progress in establishing themselves as centers of excellence in various aspects of materials science.

Among the developing nations of the world, India has been one of the major producers of steel. With seventeen million tons per annum capacity, it is the fifteenth on the list of large producers of steel in the world. Its growth rate in the steel production

is 5-6% per annum. The trend is towards high-quality steels. Special equipments such as vacuum arc decarburization (VAD) and ESR, have been installed, and a number of new thermomechanical processing technologies have been introduced. According to Dr. Bannerjee, Director of the National Metallurgical Laboratories, who reviewed the status of the steel industry and research in India, a number of improved quality versions of line pipe steel such as API X65, X70 and X80 were in different stages of development. These are to cater for the needs of the sour gas applications. Thermomechanical processes (TMP) for rounds have also been introduced with the installation of TEMPCORE technology at Tata Steel plant. Work on TMP of microalloyed forgings has been started at the Tata and Durgapore Steel plants. Accelerated cooling practices for improved rebars have been adopted by some mini steel plants. Research in steel metallurgy in India is mostly user motivated.

Dr. Allan Brownrigg of the BHP Steel Co. Melbourne, reviewing activities in Australia, stated that in Australia the major emphasis was on process metallurgy. There was no ongoing basic research. Some of the research projects funded by the BHP at its Corporate Research Labs and universities, such as Wollongong University, are product oriented. BHP, the largest plant in the country, produces 7 million tons of steel (100% continuous casting). The production facility is equipped with the TMCP technology. Tonnage steels with YS (full strength) between 250-350 MPa is in everyday use. High-strength steels with YS higher than 400 MPa are in less demand. These are produced by Bisalloy Steels (QT-plates), Camsteel (high alloy engineering steels) and BHP formable strip steel. The rest of the demand is met by imports. Current research areas include developing new steels such as HSLA 80, 550 MPa QT-steel and 480 MPa low carbon forging steel.

The Army Research Office was represented by Dr. Kylasam Iyer, who reviewed the state of the steel industry in the United States, and gave examples of the type of research that ARO was supporting in ferrous metallurgy. He described the work of Professor Rod Clifton of Brown University, who is studying the effect of the microstructure of steels and their dynamic behavior. Professor Clifton is well known for his contributions in the area of developing new techniques and instrumentation for the characterization of high-strain rate behavior of materials. Also supported by ARO are studies on the development of ultrahigh-strength steels with high-fracture toughness and stress corrosion crack resistance, designed from the first principles by Professor Gregory Olson's group at the Northwestern University.

In his keynote paper, Professor H. I. Aaronson showed that despite research extending back to the beginning of this century, the kinetics of the proeutectoid ferrite reaction in high purity Fe-C alloy system is not fully understood. The situation with the Fe-C-X systems is even less satisfactory. Interpretation of the measurements of ferrite nucleation kinetics at grain boundaries is hampered by ignorance of both critical nucleus shapes and of the boundary orientation dependence of austenite-ferrite boundary energy in Fe-C and Fe-C-X alloys. He stated that current evidence indicates that a combination of the interfacial diffusion of alloying elements and solute drag-like effect were the most likely mechanisms involved in the ferritic growth kinetics.

In a very interesting paper, Professor A. J. De Ardo Jr. of Pennsylvania State University reported the results of a thorough study of the influence of the processing variables such as austenitizing time, finish rolling temperature, and cooling rate on the microstructure and mechanical properties of Ti-B microalloyed HSLA steel with composition: C, 0.06%; Mn, 1.35%; Si, 0.31%; S, 0.01%; P, 0.03%; Al, 0.03%; Ti, 0.08%; Cr, 0.05%; and B, 0.0007%. The alloy produced in 3-ton heats was cast into 100 × 100 mm cross-section ingots, which were homogenized at 1200°C, before rolling. The rolling schedule consisted of four passes in the crystallization zone (1150°-1000°C), and four passes in the noncrystallizable zone (950°-800°C). The total deformation in the roughing stage was 68% with a cumulative rolling reduction of 3.2%. Two finishing rolling temperatures, 850°C and 800°C were used and followed by air cooling (AC) or spray water cooling (SWC). Finish rolling at 850°C and 800°C followed by AC resulted in a polygonal ferrite-pearlite microstructure. The strength-ductility combination of this class was superior when finished rolled at 800°C. In addition the room temperature and −40°C impact energies for the steel air cooled from 800°C was found to be higher. A change from air to water cooling led to the change from the ferrite-pearlite to ferritic-bainite microstructure. Finish rolling at 850°C followed by SWC resulted in a coarse bainitic structure, while a lower finish rolling temperature (800°C) yielded a polygonal

ferritic-massive bainite structure. Typical properties achieved were: Coarse bainite—YS, 450 MPa; UTS, 600 MPa; elongation, 25%; impact energy at RT and −40°C 150 and 90J respectively. Massive bainite—YS, 375 MPa; UTS, 580 MPa; elongation, 28%; impact energy at RT and −40°F 150 and 90J respectively. Transmission electron microscopic investigation showed large carbide particles at the interface of elongated ferrite laths in addition to finer precipitates within the lath. EDX analysis of the fine precipitates indicated primarily TiS compounds. In a second paper, Professor De Ardo reported the historical development of the HSLA-100 in the mid 1980s as a cost effective alternative of HY-100 for surface and submarine construction by the U.S. Navy. HSLA-100 differs from the HY-100 in the following way:

1. a lower carbon content to improve weldability,
2. the addition of copper to retard the rate of overaging and to lower Ac temperature,
3. addition of Nb to facilitate effective austenite conditioning during controlled rolling.

He illustrated these points by presenting experimental data.

Dr. Tomo Tanaka of Kawasaki Steel Techno-Research Corporation, gave an overview of the development of the thermo-mechanical controlled rolled processing of high-strength steels in Japan. He explained that the essence of controlled rolling lies in deforming austenite in the noncrystallization region, thereby increasing the ferrite nucleation sites. While the essence of accelerated cooling lies in the supercooling of deformed austenite and thereby increasing the ferrite nucleation rate. The combination of controlled rolling and interrupted accelerated cooling, which is called the thermo-mechanically controlled rolled process (TMCP) enhances ferrite transformation at high-temperature region, and bainite/martensite transformation at low-temperature region, which in turn results in homogenous, fine grained ferrite structure interspersed with low-temperature transformation products. This gives the TMCP steels excellent low-temperature toughness, low-carbon equivalent and superior weldability in terms of susceptibility to weld cracking and toughness at the heat affected zone. Dr. Tsukada of NKK Corporation, further elaborated on the mechanisms involved in TMCP in his paper and gave statistical data on the capabilities of various steel mills in the world related to this technology, including applications.

One of the two papers on microalloyed steels was given by V. Ramaswamy of the Research and Development Center of the Steel Authority of India Ltd., Ranchi. He stated that the Steel Authority of India Ltd (SAIL) entered the high-strength steel scenario with a successful development and production of Nb-microalloyed high-strength plates and channels for structural applications in 1975. In the second phase of this program API X-60/X-65 were then developed for the natural gas sector. These required accelerated cooling following the controlled rolling. He discussed the development of acicular ferrite/bainite microstructure responsible for the good combination of the strength and toughness properties of these steels. The other paper given by A.K. Roy of the Colorado School of Mines reported the beneficial effect of sulphur addition on the machinability of Nb-microalloyed steel.

A unique approach to design a high-strength steel with high toughness and good weldability was reported by Professor A.K. Patwardhan of the Department of Metallurgical Engineering, University of Roorkee. He studied a number of low-carbon Mn-Si alloys in the heat treated condition so as to arrive at the air hardening base composition Fe-4% Mn, 1% Si. The mechanical properties were determined at the as-rolled condition at two carbon levels, namely 0.022% and 0.055%, and Nb levels of 0.0% and 0.045%. At 0.022%C the YS, UTS, and elongation were respectively 800 MPa, 900 and 930 MPa, and 22.5%. The upper shelf energy(USE) was 270J, and ITT (40 ft lb) was 65°C. The addition of 0.045% Nb improved the elongation to 27.5% and the transition temperature to 90°C. He also reported that the addition of misch metal (composition 0.035%C, 4.5% Mn, 0.05% Nb with 0.01% misch metal) rendered the inclusions spherical and improved the toughness. This composition has potential for low-cost, easy-fabrication steel; therefore a patent application is under process. Professor Young Gill Kim of the POSTECH, Korea, reported an Fe-Mn-Al-C alloy needed for the new automotive sheet material. The base alloy has 25% Mn and 0.2%C. Al was found to be an important variable. When it was less than 0.5%, the strain induced phase after the tensile deformation at room temperature was HCP epsilon martensite. However, at 1.0% Al, deformation twins formed, which gave rise to increase in strength with no loss of formability. 30Kg heats melted by VIM in ingots, which were hot rolled

followed by cold rolling to 0.8 mm thickness. These sheets after annealing at 1000°C for 15 min showed YS, UTS and elongation of 20 kg/mm^2, 60 kg/mm, and 60% respectively. The formability diagram of this steel showed that it was comparable with that of the currently used ferritic automotive steel. This steel also exhibits good weldability. According to Professor Kim, in Korea this steel is being actively evaluated by the automotive industry.

I discussed with Professor Patwardhan and Professor Kim the possibility of collaboration on the scaleup and characterization of the composition developed by Patwardhan, which would be much cheaper and easy to produce than Professor Kim's composition. Professor Kim showed considerable interest in this proposal and the two agreed to exchange data and then develop some kind of joint program at POSTECH, where the facilities for pilot scale melting and processing are more modern than those available in India.

A large number of papers dealt with characterization of various HSLA steels as influenced by thermomechanical processing, characterization of the physical metallurgy of products and applications. In the area of applications, Ernest J. Czyryca of the David Taylor Research Center, described the ongoing programs at the David Taylor labs to develop HSLA 80 and HSLA 100 steels for the submarine hull structures, which has the critical requirement of good weldability with no dependency on heat treatments. The technology that is being explored is that of the thermo-mechanically processing of ultra-low carbon bainite (ULCB) and accelerated cooling/direct quenching(AC/DQ). The research has demonstrated cooling-rate insensitive-weld metals with 125 ksi yield strength, high-impact toughness in the multipass deposits with welding heat input up to 120 kj/inch. He also briefly described the TITLE 3 program under which these steels are being produced in Japan (Kolbe and Nippon) for evaluation in the United States (Bethlehem and Luken). The objective of the program is that if the AC/DQ technology developed in Japan meets the requirement of the U.S. Navy, the facility as designed and produced in Japan will be acquired by the United States. Interestingly, while the science of the TMCP is well established in the United States, the United States does not have the industrial scale TMCP/AC facility. Dr. Tsukada of the NKK, in his keynote speech, indicated that these facilities were available in Japan, Korea, Germany, but not in the United States. Dr. K. Kurabayashi of the Institute of Space and Aeronautic Science described the physical metallurgy of the maraging steel used in the motor case of the first and second stages of the Mu rocket, which is the scientific satellite launch vehicle in Japan. The alloy developed has a UTS of 2.0GPa, achieved by the addition of small amount of boron and boride former element, which can precipitate on the dislocations and retard the recovery and the recrystallization of the reversed transformed austenite.

In the high-speed rotating machines for power generation, there is an increasing demand for high-strength ferrous alloys with moderate-soft-magnetic properties. In connection with this, high-strength steels such as 4320 and 4340 under different heat treatments have been investigated, and it has been reported that detrimental effect of carbon can be reduced through spheroidization. Dr. Mohanty and his associates reported that by spheroidizing carbides in microalloyed steels with 0.2%C, 1.7% Mn, with Nb, V, and Ti as microallying elements, it was possible to develop high magnetic induction and permeability with moderate coercive force at yield strength of about 500 MPa.

A number of presentations were given about welding of high HSLA steels. M.G. Vassileros of the David Taylor Research Center, discussed the development of high-strength low-carbon weld metal at his laboratory. He showed that ULCB weld metal with 0.02%C can develop YS in the range of 650-850 MPa, and it is resistant to hydrogen cracking and thus minimizes the need for expensive thermal treatment in the welding process. Under a joint program with NRL, Dr. Sen of the Steel Authority of India evaluated the microstructure of the submerged arc welded HSLA-80 produced at the Durgapore Plant.

CONCLUDING REMARKS

Opinions expressed at the panel discussion at the end of the workshop and individual contacts during the workshop pointed to the consensus that except for Japan and to a lesser extent the United States, research on fundamental issues in ferrous metallurgy is declining. Most of the research and development is motivated by the process development and the market for improved products. During the last ten years, we have seen tremendous improvement and innovation in the refining, casting, thermomechanical processing, and the surface treatments of steels. However as Professor Aaronson and

Professor J. Szekley of MIT expressed, there is a pressing need for basic research on basic physical metallurgy and processing modeling that is crucial to the introduction of computer integrated manufacturing. According to Dr. Tomo Tanaka, in spite of the great progress in the TMCP technology, there are still problems that relate to the toughness of heat affected zone in the welded steel and to cleaning the alloy free of inclusions and undesirable segregations.

The majority of the attendees expressed need for closer collaboration in research among the various laboratories involved in steel research. Particularly the Indian researchers showed considerable enthusiasm in working on joint projects with the U.S. scientists, both in the academia and in the defense laboratories. One catalyst for such activity is that the Indian Government has a large Rupee Fund that is still available for joint U.S.-India R&D activities. It will expire in 1997. Currently, only the ONR and NSF are participating in this program. The majority of the joint projects are in metallurgy, environmental science, and oceanography. In the case of South Korea, there is no fund like the Rupee Fund; but the Korean Institutes are not short of funds and are prepared in many cases to have joint research programs with no cost commitment on the part of the U.S. laboratories.

ADVANCES IN INORGANIC FIBERS TECHNOLOGY

An International Workshop, August 13-14, 1992, Melbourne, Australia

The salient advancements reported at the workshop and conclusions resulting from the general discussion are summarized in this report.

Iqbal Ahmad

INTRODUCTION

With the space age, the advanced propulsion systems for civilian and defense applications, the need for higher fuel efficiency and emphasis on high-mobility and global-environmental concerns, it is necessary to develop materials with high-specific strength and stiffness, high-fracture toughness, and thermal stability as well as easy processibility at low cost. Presently, only glass and carbon fiber reinforced organic polymer composites with a maximum use temperature of 300°C are well established industrial products. Materials to be used at a temperature higher than 300°C, such as those required for gas turbine engines and supersonic aircraft structures, involve fiber reinforced metals and ceramics. Because of their low density, high-temperature stability and high stiffness, the preferred materials for fibers are high-temperature carbides, nitride, oxides, and borides. A number of such fibers have been made both in the western countries and in Japan and are at this time in various stages of development. Tables 1, 2 and 3 reproduced from the review paper entitled "High Performance Inorganic Fibers (for reinforcement)" published in Tokyo by Kogyo Zairyo, Nov. 90, P-57-62, list the carbides, nitride and oxide fibers. Of the carbides, Nicalon (Nippon Carbon) and Tyranno (Ube) are the only ones that are being marketed. Others are still being developed. None of the nitride fibers are commercialized as yet. Some of the oxide fibers are on the market. FP fiber developed by Du Pont, was considered to be a breakthrough for making metal matrix composites, an economically feasible product. But the problem of handling and relatively low-thermal stability, has dampened the enthusiasm. Du Pont also developed PRD-166, an improved fiber which contains 15% zirconia and has superior mechanical properties. However, because of the high cost of production with practically no market, has forced Du Pont to decide to cease all development work on these fibers. Similarly, Dow Corning has stopped all R&D efforts on the HPZ and MPDS fiber developed under the DARPA funding.

In Japan, the Toyota Motor Company has commercialized pressure cast pistons that use lower cost oxide fibers. This can be said to be the only instance where fiber-reinforced metal-matrix composites have been successfully applied in a commercial system. On the whole, however, the progress in scaling up a fiber-reinforced metal or ceramic composite to an economically feasible product is extremely slow.

The major barrier for the development of economically feasible composite systems is the cost of the fiber. Funatani (M.J. Koczak et al., "Inorganic

Table 1 — Chemical Composition and General Properties of Silicon Carbide Fibers

Manufacturer	Name of fiber	Chemical composition (wt%) Si	C	O	Ti	Density (g/cm³)	Fiber diameter (μm)	Tensile strength (GPa)	Tensile elastic modulus (GPa)	Reference
Nippon Carbon	Nicalon	59	30	11	—	2.55	12/14	3.0	220	On the market
Ube Industries	Tyranno	51.0	27.9	17.7	3.1[1]	2.37	8.5/11	2.74	206	On the market[2]
Textron	SCS-6	70	30 (including carbon core)	—	— N	3.0	140	3.45	400	SiC is CVD-coated on carbon fibers (33 μm)[3]
Dow Corning	MPS	59.1	29.3	6.28	0.09	2.62	10-20	1.7	210	Being developed[4] (precursor polymer method)
Textron	—	?	?	?	—	—	6-10	2.8	280-315	Being developed[5] (precursor polymer method)

(Notes) (1) T. Yamamura, et al., J. Mater. Sci., 23, 2591 (1988). Ti content: about 2 percent according to a report. (Tai-Il Mah et al., CERAMIC BULLETIN, Vol. 66, No. 2, 305 (1987))
(2) Value in catalogue of Ube Industries, 1989. 10.5,000 s.
(3) Value in catalogue of Textron, 0481-16-2M.
(4) J. Lipowitz, G.E. LeGrow, T.F. Lim, N. Langrey: Ceram. Eng. Sci. Proc. 9 [7-8] pp 931-942 (1988).
(5) Tai-Il Mah et al., CERAMIC BULLETIN, Vol. 66, No. 2, 305 (1987).

Table 2 — Chemical Composition and General Properties of Si-N(Si-N-C) Fibers

Manufacturer	Name of fibers	Chemical composition (wt%) Si	N	C	O	Density (g/cm³)	Fiber diameter (μm)	Tensile strength (GPa)	Tensile elastic modulus (GPa)	Reference
Tonen	Silicon nitride fiber	59.8	37.1	0.4	2.7	2.5	10	2.5	250	Being developed[1] (precursor polymer method)
Dow Corning	MPDZ	47	14.5	29	7.5	2.2-2.3	10-15	1.75	175-210	Being developed[2] (precursor polymer method)
Dow Corning	HPZ[3]	59	28	10	3	2.32	8-15	1.75-1.80	140-175	Samples distributed (precursor polymer method)
	[4]	60	27	9	3.4	2.48	10-12	2.06	165-220	
Ethyl	Si-C-N	55.8	27.8	14.8	2.1	2.5	28±5	3.16±1.0	227±6	Being developed[5] (precursor polymer method)
Ethyl	Si_3N_4	58.8	40.9	0.4	2.0	2.2	34±5	1.44±0.75	137	Being developed[5] (precursor polymer method)
Okamura of Tohoku University	SiON	54	31	—	15	~2.3	11-13	1.80±0.37	139±17	Research paper[6] (precursor polymer method)

(Notes) (1) Tonen's technological material (obtained at 1st JAPAN SAMPE Exhibition, December 1989).
(2) L.C. Sawyer, M. Jamieson, D. Brikowski, M.I. Haider, J. Am. Ceram. Soc., 70[11]798-810 (1987).
(3) J.E. Lane, A.R. Pebler, Ceram. Eng. Sci. Proc., 10[9-10] pp 1213-1222 (1989).
(4) 1990, January 14-17, Am. Ceram. Soc. Coca Beach Meetingg, Table-top Exhibition.
(5) Technological material of Ethyl Chemical Group.
6) K. Okamura, M. Sato, Y. Hasegawa, Chem. Lett. pp. 2059-2060 (1984).

Table 3 — Chemical Composition and General Properties of Al_2O_3 Type Fibers

Manufacturer	Name of fibers	Chemical composition (wt%) Al_2O_3	SiO_2	B_2O_3	ZrO_2	Density (g/cm^3)	Fiber diameter (μm)	Tensile strength (GPa)	Tensile elastic modulus (GPa)	Reference
Sumitomo Chemical	ALTEX	85 (γ-Al_2O_3)	15	—	—	3.3	10/15	1.8	210	Marketed [1]
3M	NEXTEL312	62 ($9Al_2O_3 \cdot 2B_2O_3$ + amorphous SiO_2)	24	14	—	2.7-2.9	10-12	1.70	150	Marketed [2]
3M	NEXTEL440	70 (γ-Al_2O_3 + mullite)	28	2	—	3.05	10-12	2.00	190	Marketed [2]
3M	NEXTEL480	70 (mullite)	28	2	—	3.05	10-12	1.80	220	Marketed [2]
DuPont	FP	99 α-Al_2O_3	—	—	—	3.9	20	1.4	385	Marketed [3]
DuPont	PRO-166	75-85	—	—	15-25	4.2	20	2.1-2.45	385	Being developed (small sample available) [4]
Mitsui Mining	ALMAX	99.5 α-Al_2O_3	—	—	—	3.6	10	1.76	323	Marketed [5]

(Notes) (1) Catalogue of Sumitomo Chemical.
(2) 3M's catalogue of NEXTEL 312 and 440, 480 technical material.
(3) Catalogue of DuPont.
(4) Tai-Il Mah, et al., CERAMIC BULLETIN, Vol. 66, No. 2, 305 (1987).
(5) Catalogue of Mitsui Mining.

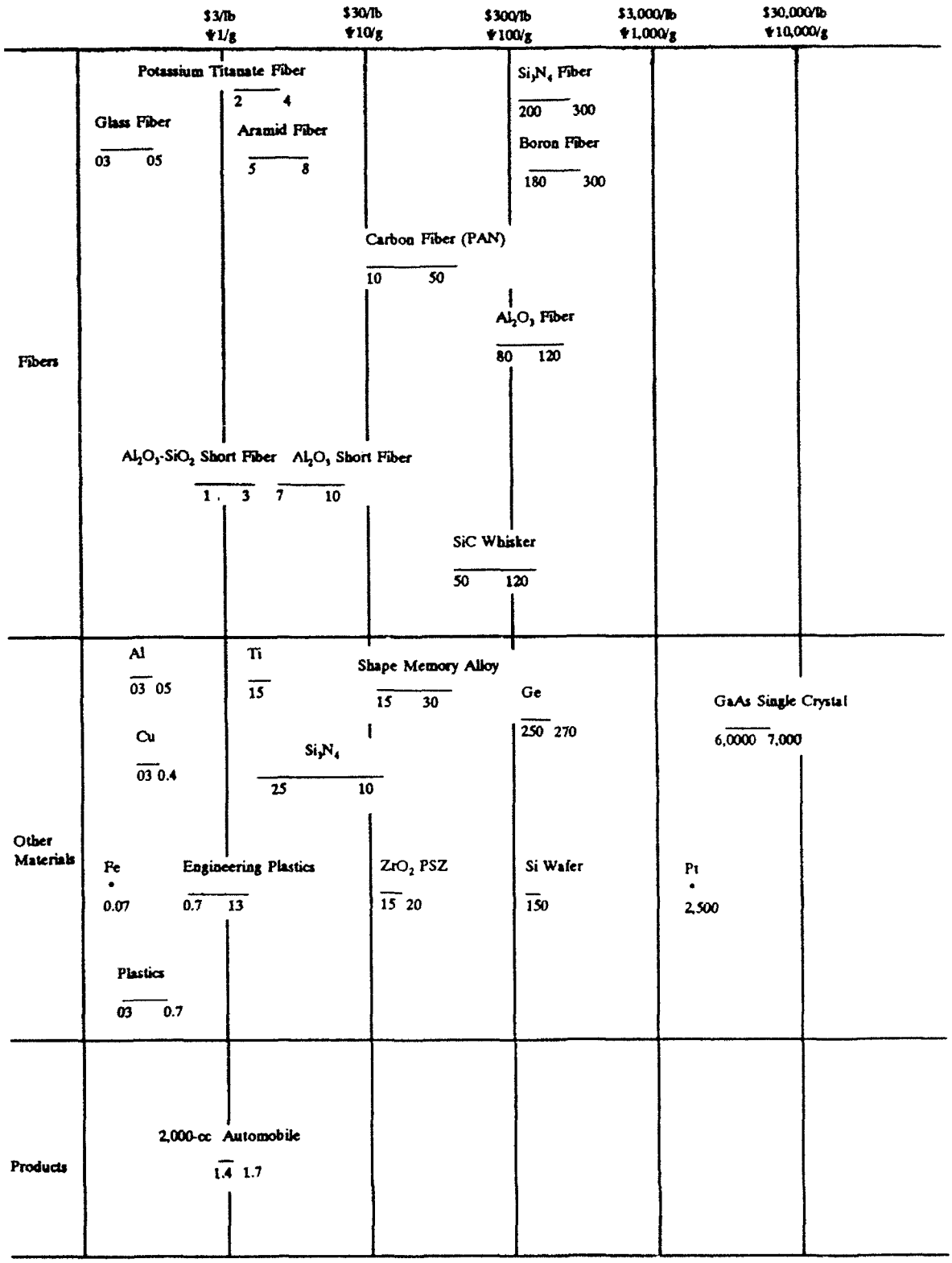
Composite Materials in Japan — Status and Trends". Scientific Monograph ONRFE-M7, Nov. 89. p-10) of the Japan Fine Ceramic Center has persuasively demonstrated this fact. He calculated the cost per pound of the advanced fibers and compared it with the cost per pound of a 2000cc automobile. This is summarized in Table 4. It will be observed that except for a very specialized application, where performance and not cost is a primary consideration, glass fiber is the only reinforcement that can be justified for use in a high-volume product such as automobiles.

To minimize the cost of production, improved or new processes are needed for the preparation of advanced fibers. Considerable work is being done to develop superior processes, and significant success has been achieved particularly in preparing fibers from the organic polymer precursors. Because of the demonstrated improvement of fracture toughness of ceramics with whiskers, there has been a renewed activity in the development of low-cost processes for the growth of whiskers of various inorganic phases such as silicon carbide and aluminum oxide. However, they are still a very expensive reinforcement.

Some interesting developments in the improvement of the mechanical properties of fibers by either modifying the composition or the secondary treatments have been reported. The beneficial effect of the addition of 3% Ti to the Si-C-O on the thermal stability is now well known, since this has led to the Tyranno fiber manufactured by Ube Industries. The effect caused by the addition of other elements is also being explored. An interesting development reported by Dr. T. Seguchi of the Japan Atomic Energy Institute (JAERI) is the improvement of the tensile strength and the modulus of silicon based fibers, when, after curing in the oxidizing atmosphere, a key step in the manufacture of these fibers, they are irradiated with electrons in helium atmosphere followed by heat treatment in argon at 1200°-1600°C. Additionally, irradiation with neutrons has been reported to have increased the density of silicon carbide fibers, which in turn leads to the improvement of their tensile strength.

Another important area of concern in the advanced inorganic fibers is their compatibility with the metal or ceramic matrices, and fiber-matrix interaction when exposed to service temperatures for extended periods of time. In the United States, textron has successfully modified the surface of the SCS fiber, which makes it more compatible with aluminum alloy matrices. Sometimes it is necessary to apply a protective coating on the fiber to minimize fiber-matrix reaction during fabrication of the

Table 4 — Fiber Material Cost



Relative fiber and material cost compared to the cost of a 2,000-cc automobile. "FRM application for automotive parts," by K. Funatani, *Journal of the Japan Society of Mechanical Engineers* 89(808), 241 (1986). Reprinted by permission of the Japan Society of Mechanical Engineers.

composite and its service life. Nippon Carbon and Ube are marketing some fibers that are coated with aluminum. Superior coatings applied with low-cost processes and gaining more insight into the micromechanics of the interface are needed to successfully produce composites with superior stress rupture properties.

There is a paucity of reliable and reproducible experimental data about the mechanical behavior of the fibers. In a recent report prepared by Hong, et al., of the Institute of Defense Analysis, Washington DC, (Hong W. S. et al "Reinforcement Options for High Temperature Composites and a Comparison of High Temperature Tensile Testing Results for Ceramic Fibers", IDA Paper P-2483 Dec 90.) has demonstrated that a considerable scatter of data exists, particularly the data obtained at high temperatures, reported by even well reputed research groups at various laboratories in United States of America. Therefore, superior methods for the characterization of the mechanical properties and NDT need increased attention by the research community.

WORKSHOP OBJECTIVE AND SCOPE

In short, considerable research and development activity in the inorganic fiber technology exists internationally. The objective of this ARO-FE and DARPA sponsored workshop was to bring together active workers in the field to review the state of the art, and to identify critical areas that need emphasis for future R&D, so that economically feasible materials needed for the 21st Century are successfully developed in a reasonably length of time.

The scope of the workshop presentations was limited to the following issues:

(1) Limitations of the conventional processes and possible approaches to produce high quality fibers and whiskers at affordable cost.

(2) Approaches to improve the fiber matrix interface, including the modification of the surface chemistry by the application of the diffuse coatings suitable for the selected matrix materials.

(3) Study of the influence of additional elements and irradiation on the mechanical properties of the fibers, compatibility with the matrix and thermal stability of the fiber.

(4) New thermally stable and compatible fibers.

(5) Micromechanics of fiber failure and fiber-matrix interfaces. New techniques for the characterization of fibers.

Nineteen papers were presented at this workshop. They were followed by a panel discussion. The papers will be published in a special issue of *Composites Science and Technology*. Highlights of the work reported are summarized in the following section of the report.

WORKSHOP SUMMARY

As already mentioned in the introduction, the most successful fiber to date has been the Si-C-O_x, particularly the Nicalon fiber that is manufactured and marketed by the Nippon Carbon. Therefore, more papers on this fiber were presented than on any of the others. Dr. Ishikawa, of the Nippon Carbon, described the original process developed by Yajima, in which the dimethyl dichlorosilane polymerized to polycarbosilane (PC) with a mean molecular weight of 1000-2000, is spun into the green fiber followed by subjecting it to oxidative curing and final pyrolysis at 1600°C. This 12/14 μm diameter fiber is the commercially available fiber that is being used worldwide for the development of advanced ceramic matrix composites. However, it is now well recognized that during the oxidative curing the fiber picks up as much as 11% oxygen, and because of this its elastic modulus is low and its strength degrades when exposed to temperatures higher than 1200°C. Recent work by Dr. Seguchi of JAERI and Dr. K. Okamura of the Tohoku University has shown that during the oxidative curing, electron irradiation of the fiber in oxygen free atmosphere can reduce its oxygen content to less that 0.5wt%. This fiber, after final heat treatment, has superior thermal resistance. It has been shown to maintain room temperature tensile strength as high as 2GPa after 10-h exposure at 1500°C. Nippon Carbon has named it HI-NICALON fiber. Based on these encouraging results, Nippon Carbon has received a JRDC contract to scale up this process, by 1995. Dr. Hiroshi Ichikawa of the Nippon Carbon R&D Laboratory in a follow-on presentation reported the mechanisms of the degradation of Nicalon fiber and the Nicalon-Silicon nitride composite and gave further details of the electron irradiation process. He stated that irradiated Nicalon fiber

improved its elastic modulus from 220GPa to 26O-GPa.

Professor M. D. Sacks, of the University of Florida, reported that the oxygen content of the Si-C-O_x fiber can be reduced without resorting to irradiation, which may be expensive and difficult to scale up. In his process, which differs from that of Yajima, polycarbosilane (PC) with a molecular weight of 5,000-10,000 (as compared with 1,000-2,000, used in Yajima process) synthesized by pressure pyrolysis of polydimethylsilane is spun in to fiber in nitrogen atmosphere. This fiber remained highly soluble but did not melt during subsequent heat treatment. The green fiber was pyrolysed in the range of 750°-1000°C, followed by a heat treatment in argon (Ar) at 1200°-1700°C. The oxygen content of the fiber was less than 2wt%. It has a smooth surface and was capable of maintaining tensile strength of 1.9GPa after exposure to 1400°C. Further improvement in properties were expected through removing excess carbon and impurities and suspensions from the oligomeric liquid by filtration.

An alternative method for curing polycarbosilane (PC) was reported by Dr. Yoshio Hasegawa of the Research Institute for Special Inorganic Materials, Ibaraki, in which the fiber spun at 370°C from PC with an average mole weight of 2060, is exposed to unsaturated hydrocarbons such as cyclohexene, l-hexyne or 1-octyne, followed by heat treatment in argon at 1500°C. The resulting fiber has low-oxygen content and is reportedly as thermally stable as the electron irradiated Nicalon fiber. Called the Chemical Vapor Curing process (CVC), it is expected to be more economical than the electron irradiation process.

Dr. J. Lipowitz of Dow Corning United States of America, is studying the influence of doping with boron on the properties of the Si-C-O_x fiber. He reported an elastic modulus of 450GPa for some of these doped microcrystalline fiber specimens, which retained 87% of their tensile strength after exposure to argon at 1800°C for 12 h. However some fibers with excess carbon had low modulus.

Responding to the issue of cost for the fabrication of inorganic fibers, Prof. J. Economy of the University of Illinois discussed the preparation of BN fibers by reacting boron oxide filaments with ammonia over a temperature range of 350°-850°C. The fibers were then stretched (17%) and pyrolysed at 2000°C, which resulted in the orientation of the layered structure. He stated that this process was being scaled up at his laboratory. BN fibers display a very good thermal stability and are resistant to many molten metals. Dr. Y. Kimura of the Department of Polymers Science and Technology, Kyoto Institute of Technology, described the preparation of BN fibers from an organic preceramic obtained by thermal decomposition of B, B, B tri-methylamine borazine (MAB) containing 10 wt% of lauralamine (LA). The condensate was spun melt into fibers that were then hydrolysed to make them infusible. Pyrolysis at 1000°C in ammonia followed by sintering up to 1800°C in nitrogen gave a product that had a tensile strength of 1 GPa, with a modulus of 78 GPa. The fiber showed exceptional increase in strength when sintered at temperatures higher than 1400°C.

Titanium diboride has high elastic modulus, reasonable low density, a moderate thermal expansion coefficient and is thermodynamically compatible with a number of potential intermetallic matrices. Professor R. J. Diefendorf of Clemson University, U S.A., described the preparation of TiB_2 fibers by chemical vapor deposition using gas mixtures of titanium tetrachloride, boron trichloride, hydrogen, and hydrogen chloride. He discussed a simplified finite element dynamic analysis model to describe the deposition of the TiB_2 phase from a cold wall reactor at atmospheric pressure.

An interesting process named as laser assisted chemical vapor deposition (LCVD) was reported by Professor F. Wallenberger of the University of Illinois , in which thermally nucleated solid phase is withdrawn from the hot focal point of a laser beam located in a chamber containing the reactant gases. The solid phase in the focal zone thus forms a continuous fiber, the diameter of which depends on the temperature of the focal zone, reactant gas composition, and deposit withdraw rate. The apparatus consists of an optical bench with a continuous 5W Nd-YAG laser, a small reaction chamber in an inclosed laboratory hood, a system for delivering feed gases, a microscope attached to the reaction chamber to observe the growing fiber, and a computer control console to drive the gas supply. Boron fibers were grown in this way by using a gas mixture of 40% diborane 60% hydrogen, at a deposition temperature in the range of 1000° to 1500°C. The diameter of the fiber could be controlled between 9 and 100 μm. This fiber showed a strength in the range of 3-7GPa. The strength increased with increased chamber pressure. Ultrastrong fibers approaching theoretical strength (7.6 GPa) were grown at 0.6 mm/s at the upper end pressure of 1020KPa.

Professor F. Wallenburger suggested that this would be an excellent laboratory technique for evaluating the feasibility of the preparation and the quality of new potential reinforcement fibers. He also demonstrated that the technique could be used to form microsprings and other interesting microcomponents to use in electronic devices.

Dr. Anthony Bunsell, of the Ecole Nationale Superior de Mines de Paris, gave an overview of the activity in the fiber technology. He stated that a fiber similar to the Dow Corning's HPZ was made by Rhone Poulenc in France, however this work had been discontinued. Hoerst has developed such fibers, but only at laboratory scale. In the UK ICI's Saffil fiber, which is a major activity essentially is a mixture of alpha alumina and silica. Major use of this fiber is as high temperature insulation. This fiber degrades when exposed to temperature around 1200°C by grain growth, and the fiber creep above 1000°C. In his opinion, to overcome this problem, single crystal alpha alumina fiber such as saphikon is a clear choice for a reinforcement with potential application at 1200°C or higher temperatures.

The nature and design of the interface are critical for the effective performance of the fibers as reinforcements. Dr. A.J Phillip of the Cambridge University, UK, and Professor Motosugu Sakai of the Toyohashi University addressed this issue. Dr. Sakai stressed that in order to attain increased toughening in brittle/brittle composite system, it is necessary that the interface has an optimum bonding force that is strong enough for stress transfer, yet weak enough for considerable interface debonding and subsequent fiber pull out. In his paper, he discussed the fracture toughness for the first cracking of brittle matrix composites such as carbon-carbon and carbon-silicon nitride composites in relation to the ratio of the fiber and matrix elastic moduli Ef/Em as well as to the interface bond nature. Dr. Jim Di Carlo of the National Aeronautics and Space Agency(NASA) discussed the creep-related limitations of current polycrystalline ceramic fibers. At higher temperatures, the use of ceramic fibers in the ceramic matrix composites has been shown to loose strength and stiffness, sometimes well below those where similar effects occur in potential ceramic matrices. He addressed the question that whether for any application, say, higher than 800°C, the creep related change in structural properties displayed by current ceramic fibers can be tolerated, and if not, what minimum properties should be aimed at. Because of the service-life requirements, in which dimensional stability is an important factor, a fiber creep strain of less than 1% is assumed for a constant service stress of 100MPa. For a typical fiber Young's modulus of 200GPa is assumed; this imposes an upper limit of 50 for normalized creep strain (NCS). He argued that for composites, the lives of which are limited by the maintenance of constant stress and avoidance of catastrophic failure, NCS much less than 50 will be required. He described a simpler method of evaluating and comparing the creep strain of fibers of silicon carbide, silicon nitride, and alpha alumina. It is based on a bend stress relaxation test as described in Dr. Carlo's paper. Assuming a service-life of 300h and an optimistic requirement of NCS=50, he showed that the currently available silicon and alumina based fibers can attain upper use temperature of about 1200° and 1000°C respectively. He stressed the need for improved processes for the fabrication of more creep resistant fibers.

CONCLUDING COMMENTS

At the end of the workshop, the issues mentioned in the introduction were discussed. There was a consensus that in the case of Si-C-O_x class of fibers, the major cause for the degradation of the fibers, when exposed to temperatures higher than 1200°C, was the presence of oxygen picked up during the oxidative curing of the green fibers. As the presentations made at the workshop indicate, significant progress is being made in overcoming this problem. It appears that approaches like those used by Sacks (UF) and Hasegawa, may prove to be more economical than the electron irradiation. On the cost issue, the majority of the participants expressed that the overall market of the advanced inorganic fibers in the world was very small. And perhaps will remain small, as they would be needed mainly for specialized applications. Therefore, most of the large companies do not consider worthwhile setting up a production facility for such a small-volume product. In Japan, however, companies like Nippon Carbon or Ube continue to develop these fibers. One aspect of their effort is the search of uses other than high-temperature structures. For example, as Dr. Ishikawa stated in his paper, the Nippon Carbon was investigating developing NICALOCERAM for use

on roller working in molten zinc for galvanized iron sheets. Using Nicalon for microwave transmission is also being considered. Dr. A. Bunsell suggested use of Nicalon reinforced ceramics components such as spinners for glass industry.

However, there was no plausible recommendation for a very large application of these fibers.

Questions were asked, as what temperature is the industry looking for to use for these fibers. It was suggested that even for the high temperature turbine application, the use of temperatures 1500°C may be the practical limit. For these applications, high-cost and sophisticated fibers and coating technology may be justified. Next, come the fibers that are expensive but stable in air up to 1300°C. Those fibers as they have been reported at this workshop, are now available at least at experimental scale. A possibility exists that their cost of production will go down with increased production capacity. They will be suitable for reinforcing metals and to obtain medium cost composites. Finally, there are low-cost fibers that are good up to 1000°C for tribological applications and insulations. Therefore, it is useful to classify the fibers according to the use of temperature, and then evaluate their potential and limitations of large scale production.

It was also brought to the attention of the attendees that most of the high-temperature tensile-property data reported in the literature, and at this workshop, were misleading, as they represent the tensile strength of the fibers at room temperature after they had been exposed to high temperatures. What is needed are the tensile-strength data at temperature and under load. The general opinion was that not much reproducible high-temperature data were published in the open literature.

Dr. DiCarlo of NASA stated that the best available super-alloys used in a gas turbine engine in advanced aircraft are good up to 900°C. For short special missions and special applications, such as the IHPTT project, materials thermally resistant up to 1200-1300°C may be the best available under the present technology. Dr. Bunsell said that Rolls Royce was looking for materials good up to 1500°C.

Discussion relating to the design of the fiber--matrix interface led to questions about the effect of the surface roughness of fibers, nature and thickness of coatings, chemical modification of surfaces, and compressive stresses on the fracture toughness of the composites. The main conclusion was that there was a need for deeper understanding of all these aspects of the interfaces. Need for standardized NDT of the fibers was strongly expressed. The test developed by NASA for the evaluation of stress relaxation and creep strain at high temperatures, as described by Dr. DiCarlo, was considered to be quite good. Dr. DiCarlo stated that this test procedure was being published in the form of a paper and will be submitted to ASTM for standardization.

THIRD ASEAN SCIENCE AND TECHNOLOGY WEEK REGIONAL OCEAN DYNAMICS CONFERENCE SEPTEMBER 1992 SINGAPORE

"Modelling techniques—An effective tool to understanding the influence of sea level in the ASEAN region" was the theme of the meeting held in Singapore. Fourteen papers were presented by scientists from Australia, Canada, Malaysia, Indonesia, the Philippines, Singapore, and Thailand. The focus was on tides in this area, where the Western Pacific and Indian Ocean connect through a complex weir of straits and islands. The vast majority of models used the finite difference technique and were almost uniformly designed for practical purposes such as oil spill tracting. The papers were presented in the context and as a progress report of the ongoing ASEAN Regional Ocean Dynamics project started in 1989. It is the continuation of the initial Tides and Tidal Phenomena project started in 1985. This is a long-term multinational effort to understand the oceanography of the region augmented by a linked system of high-quality tidal stations and moored and bottom arrays of oceanographic measuring devices.

Pat Wilde

INTRODUCTION

The third Science and Technology Week conference and exhibition was held in Singapore from 21 to 24 September 1992. This meeting of ASEAN (Association of South East Asian Nations: Brunei, Indonesia, Malaysia, Philippines, Singapore and Thailand) occurs once every three years and is held in conjunction with a meeting of the Science and Technology Ministers from the ASEAN countries. The two previous conferences were held in Malaysia and in the Philippines, respectively. The theme for the 1992 meeting was "Socio-Economic Growth in ASEAN through Science and Technology". The meeting was sponsored by ASEAN COST (Council On Science and Technology). This meeting has special significance to Singapore since September is annually celebrated as being the Technology Month, emphasizing the importance of Technology to the economy of Singapore. Several simultaneous conferences were held during the week:

1. Biotechnology: 10 sessions
2. Food Science and Technology: 10 sessions
3. Nonconventional Energy: 10 sessions
4. Marine Science: Living Coastal Resources: 14 sessions
5. Marine Science: Regional Ocean Dynamics: 5 sessions
6. Microelectronics and Computers: 11 sessions
7. Material Science and Technology: 9 sessions
8. Science and Technology Policy: 2 sessions.

The two Marine Science Conferences were further divided into theme technical sessions. For Living Coastal Resources, the sessions were,

a. Remote Sensing Applications;
b. Colonization and Recruitment of Artificial Substrate;
c. Reef Benthos Studies;
d. Mangrove Community Function, Seagrass Community Structure and Biology;

e. Seagrass-Associated Fauna;
f. Fish Habitats and Biology;
g. Plankton and Nutrient Dynamics;
h. Soft Bottom Communities; and
i. Management and Conservation.

For Regional Ocean Dynamics, the sessions were,

a. Tidal Measurements;
b. Modelling Technique; and
c. Modelling Techniques in the ASEAN region.

I attended the Regional Ocean Dynamics Conference and will report in more detail as follows.

REGIONAL OCEAN DYNAMICS CONFERENCE SESSIONS

This conference is basically the report of the ASEAN-Australia project on "Tides and Tidal Phenomena" Phase I: "Tides and Tidal Phenomenon Project" initiated the first "simultaneous and comprehensive measurement" of tides in the ASEAN area. Phase II: is the "Regional Ocean Dynamics project. The theme of the session was "Modelling Techniques—An Effective tool to Understanding the Influence of Sea Level in the ASEAN Region." As mentioned above, the conference was divided into three sessions.

TIDAL MEASUREMENTS

The initial session was chaired by Dr. George Cresswell of the Commonwealth Scientific and Industrial Research Organization (CSIRO) Hobart, Tasmania, had three papers. The lead paper was by Professor G. W. Lennon, Flinders University of South Australia, on "The ASEAN Seas and Their Links With Climate." The discussion was a summary of activities of the Physical Marine Sciences projects under the auspices of the ASEAN/Australia Economic Cooperation Program (AAECP), which began in 1985. The initial program on tides and tidal phenomena had the goal of building a sea level data bank for the region and had to deal with the practical issues of operating and maintaining tidal stations as well as training personnel. Realizing the importance of this region to the general understanding of oceanographic processes, since the area is essentially a weir between the Pacific and Indian Oceans, the follow-on program "Regional Ocean Dynamics" was begun as a second phase in 1989. The interocean transport is estimated to be in the range of 2 to 18 Sverdrups (one Sverdrup = one million cubic meters per second) with water from the Central West Pacific warm pool moving into the Indian ocean. Thus, the characteristics of the "Indonesian Throughflow" could be implicated in the Global climatic processes that may be involved in triggering the aperiodic El Nino/Southern Oscillation (ENSO) climatic event. This event affects greatly the economy of fisheries by modification of upwelling and nutrient transport, and of agriculture by inducing drought cycles.

As a result of *Phase* I an array of tide gauges were established, each with two different sensors and three recording systems. The data are transmitted to the National Tidal Facility in Adelaide and placed into a "formal Data Bank of Sea Level and Tides" for the ASEAN community. Quality control was also achieved by comparing the results from the two gauges from the Thailand station Ko Nu and at the Raffles Lighthouse in Singapore. After allowing for calibration problems and other retrievable corrections, the records vary only to a few centimeters.

Phase II built on *Phase I* experience and extended the goals of Phase I to an understanding of the current flow and to take a 3-D approach that would include current meters, XBT (expendable BathyThermographs), and CTD (Conductivity/Temperature/Depth) casts as well as installation of 24 new tidal stations. The targeted areas are the Equatorial Straits, the South China Sea, Makassar Straits, Maluku Straits, and through the Halmahera Sea. In shallow water moorings a bottom-mounted Acoustic Doppler Current Profiler will be used. For deep water, conventional taut-wire moorings will be used. This cruise is scheduled to take place from May 1993 to April 1994 using Indonesian, Malaysian, and Singaporian research ships.

Professor Lemmon also discussed the preliminary observation that there is an inverse correlation between sea levels in the South Coast of Australia and in the South Coast of California. Also that a rise in South Australia is a precursor warning, a year in advance, to an El Nino in the Eastern Tropical Pacific.

Captain Hassan of the Royal Malaysian Navy gave the second talk on "Tidal Services by the Hydrographic Department-Royal Malaysan Navy." He discussed the history of hydrographic department and its role in cooperating with the ASEAN tidal and regional dynamics projects. Five high-quality

tide gauge stations will be maintained across the breath of Malaysia for these programs as well as for the integration of the 21 existing tide gauge stations with the ASEAN Database.

Mr. Efren P. Carandang of the National Mapping and Resources Authority, Coast and Geodetic Survey Department of the Philippines, discussed in the third paper of this session the "Preliminary Study on Sea Level Variations in the Philippine Islands." For the ASEAN tidal projects, five combinations of digital/analog primary tide gauge stations were installed along with 50 secondary stations. The primary stations are to be run continuously whereas the secondary stations will be observed from periods of time, from 15 days to several months. Thus far observations show high correlations with the direction of the Monsoon. During the Summer Southwest Monsoon, sea levels are higher and are accompanied by floods and storms (Typhoons). During the Winter Northeast Monsoon, sea level is about 10 cm lower. Long-term records from Manila Bay suggest a rising Mean Sea Level of 0.3 m that started in 1965 through 1990. Possible causes such as subsidence, increased river discharge caused by deforestation have been suggested but no conclusive explanation has been found. A lowering of 0.005 m Mean Sea Level has been noted at Jolo, an island at the southwest end of the Philippines off the coast of Borneo.

The second portion of the Tidal Measurements Session was chaired by Kasijan Romimohtato. Captain Vichai Panpruk of the Oceanographic Division, Hydrographic Department of the Royal Thai Navy, talked on "Sea Level in Thailand." Since 1940, 23 permanent tide gauge stations have been operational in Thailand. This number was increased by 5 high-quality special tide gauge stations for the ASEAN network as discussed previously. Sea level in Thai waters is influenced by the Monsoons. It lowers during the Southwest Monsoon season (Feb.-June), and rises during the Northeast Monsoon season (Aug.-Jan.) for the Gulf of Thailand is on the South China Pacific side. On the Andaman Sea, Indian Ocean side, MSL increases during the Southwest Monsoon season and decreases during the Northeast Monsoon season. Long-term trends are not obvious. Only in the upper Gulf of Thailand has the MSL risen to about 10 mm, which may be attributed to subsidence and reduction of river outflow caused by the construction of dams.

The final paper presented at this session was by Dr. Donald O. Hodgins of Seaconsult Marine Research Ltd. of Vancouver, British Columbia, Canada. This was a descriptive talk about the use of the proprietary High-Frequency Radar system based on experience in British Columbia. The system is highly portable and runs from gasoline powered generators. The basic physics are discussed and application for use in a wilderness area in Queen Charlotte Sound in Canada is described. The system has a center frequency of 12.5 MHz with a spatial resolution of 0.00391 Hz, which translates to a Doppler velocity resolution of about 3.3 cm/s for a 1 h average current radial vector sum every 5°. The range is 60 km and a coverage of 2000 km^2. Comparision with drifters was made and a *close correspondence* was seen allowing for Loran C error on the drifters. This paper was given to demonstrate potential new techniques of current measurements, which are particularly suitable for the portable field measurements in the numerous straits and passages among the islands in the ASEAN region.

MODELLING TECHNIQUES

This technical session was chaired by Dr. Hassan of Malaysia and Renato Feir, and five papers were presented. Professor N. Jothi Shankar, for his colleagues Cheong Hin-Fatt and Chan Chun Tat of the Department of Civil Engineering, National University of Singapore and Toh Ah Cheong of the Port Authority of Singapore, presented a paper entitled "On Some Experiences in the Numerical Modelling of Shallow Water Wave Equations." This paper discusses a case study of the nested tidal model by using system 2DTIDFLO for the waters near Singapore. The regional coarse scale model has a mesh size of 1 X 1 km. The central detail model covers an area of about 30 X 30 km, uses a grid space of 250 X 250 m. Guidelines used are:

1. Boundaries of the model should be chosen so the mainflows are nearly perpendicular to the boundary
2. A zone of adjustment is usually needed to provide a smooth transition from the coarse regional bathymetry to the finer detailed bathymetry of the nested model
3. Velocity boundary layer conditions may be preferred to water level boundary conditions
4. For small grids, the model bottom friction may not be able to dissipate *unwanted* wave components.

In such cases, either Verboom's or Stelling's techniques could be used. Sandra Hodgins gave J. A. Stonach's paper on "Applications of Three-Dimensional Hydrodynamic Models" They are both from Seaconsult Marine Research Ltd. of Vancouver, British Columbia, Canada. This is the second paper giving a Canadian example from the British Columbian area. The numerical model discussed calculates currents, provides advection for salinity and *inert* i.e., non diffusive scalars such as sediment, certain pollutants or plankton. Examples are given for modelling sedimentation rate, 3-D dispersion of pollutants from an outfall, velocity fields for tracking an oil spill, and a total ecosystem for predicting availability of food for juvenile salmon. Back to the ASEAN area, with a paper by J. T. Lim and N. H. Yeong of the Malaysan Meteorological Service on "A Method of Estimating Coastal Winds in the Equatorial Region." This model described here for the coast of Sarawak uses the assumption that in equatorial regions, where synoptic winds are weak, the coastal winds are cyclic reversals of land/sea breezes. The model is a 2-D modification of Haurwitz, where the driving force for the wind is the difference between the air temperature over the land and the sea. The inland extent of the wind is also modelled, which can be from 20 to 50 km from the shore. The final Canadian paper by Dr. M. G. G. Foreman of the Institute of Ocean Sciences, Department of Fisheries and Oceans of British Columbia, explores the potential of finite element methods for modelling the situation in complicated coastal geometries such as in the ASEAN waters. Dr. Foreman outlined the previous problems with the method and how most of the difficulties have been solved. The last major barrier, which is the more complicated mathematics compared to finite difference models is essentially alleviated by the availability of cheaper and faster computer systems. Again the examples are from the Pacific coast of British Columbia. The automatic gridding system TRIGRID is available for users of UNIX based workstations or of DOS-Fortran. The model described uses a Galerkin finite element method with "the governing equations 2- or 3-D shallow water equations with the continuity equation replaced by a second-order wave equation." Examples of model runs for the coastal areas in British Columbia include: tidal M2 coamplitudes, cophase and resonance; buoyancy currents at given depths; and tidal currents. Professor Abdul Aziz Ibrahim, Director of the Coastal and Offshore Engineering Institute and his colleague Dr. Ahmad Khairi Abdul Wahab, both of the Universiti Teknologi Malaysia gave a paper "Water Circulation Modelling", which was a description of the finite difference model applied to coastal situations. The Malaysian program is in Fortran and is run on a 386 DOS machine.

Use of Modelling Techniques in the ASEAN Region

The initial talks at this session on models for the Straits of Malacca were chaired by Wilson Chua of the Port Authority of Singapore. Ivonne M. Radjawane, speaker, and her colleague Dadang K. Mihardja both of the Bandung Institute of Technology of Indonesia presented a model "On Tidal Dynamics in the Malacca Strait." She described the results from a finite difference model of the M2, S2, K1, and O1 components of the tides. Grid size is 10 min (1833 m) in the East-West direction and 3 1/3 min (6111) in the North-South direction. The total area covered is 69 by 82 grid cells. The dominant tide in the strait is semidiurnal, and a part of the southern portion with a mixed semidiurnal dominant tide. The natural period is 12.52 hours (M2 = 12.41). The major influence is from the west from the Andaman Sea and the Northern Indian Ocean. The model was verified with existing data during a 14-day computer simulation. Dr. Safwan Hadi of the Institut Teknologi Bandung, Indonesia, complemented the previous discussion of the tidal model with a talk on the "Hydrodynamics Model of the Malacca Strait." This also is a finite difference model developed to look at the current patterns in the Straits. It confirmed the influence of the western side of the Straits, but also noted no effect of Monsoonal wind shifts on currents.

The final talks were chaired by Sommai Poomipol. Toh Ah Cheong of the Port of Singapore Authority presented their approach on "Computer Modelling of Oil Spilled in the Sea." The model used is a tidal hydrodynamic model specifically designed for the area around Singapore. The tidal cycle for the Straits of Singapore is 25 hours, for 16 h it flows from the West (Andaman Sea-Straits of Malacca) and for 9 h from the East. Because of the imbalance in time caused by the dominance of the Indian Ocean tides, the westerly flow is at lower velocities than the compensating easterly flow. For practical purposes this model is used directly for real-time oil spills and prediction of drift of abandoned ships taken over by pirates that still infest the

Straits. Because of the real-time nature of potential pollution problems, the model is not run in real-time. Instead a series of likely prerun scenarios are used at the initial phase of an oil spill based on the location and occurrence in the tidal cycle to initial protection and clean-up procedures. Wind is the most critical variable with respect to oil spill drift, since the tidal currents are reasonably predictable. The model is used not only for prediction of drift of oil spills but also for incasting the origin of illegal oil spills. The final paper given was by Dr. Dadang Kurniadi Mihardja of the Institut Teknologi, Bandung, Indonesia, on "Tidal Energy Dissipation on the Southeast Asian Waters." This was a model comparison of the M2 tidal energy dissipation for ASEAN waters with previous published values. Seven *passages* were examined:

1. Northwest Australia to the lesser Sunda Straits
2. Formosa Straits to Luzon
3. Sunda Straits
4. Malacca Straits
5. Mindanao to West Irian
6. Torres Straits, and
7. Philippines.

The total energy dissipation by bottom friction is 107.3 thousand MW by turbulence 106.4 thousand MW. Thus, the total energy dissipation is 213.7 thousand MW and the energy flux for the region is 214.1 thousand MW.

DISCUSSION

This first meeting of the Regional Ocean Dynamics project of the ASEAN-Australia program demonstrates the real value of regional cooperation in science. The pooling of talents and resources of this group of nations with a vast variation in economic strength, education, languages, religions, political systems, and stage of development essentially linked only by common geography and oceanography appears as a miracle to me. Despite all the differences, I certainly got the feeling of genuine cooperation and a spirit of scientific comradeship and bootstrapping to bring tidal and in general oceanographic measurements and analyses to a high international standard. The presence of a strong Canadian representation was countered by a lack of American representation, except for me as an observer and certainly not as an active participant. In fact, as far as I knew I was the only American at the whole conference. There certainly were no American exhibitors (there were two Russian booths) and I saw no Americans at the various social functions. In fact, I may have had to suffer a grievous insult as one lady came up to me and asked: "Are you from Australia?"! The lack of a U.S. presence was sad as even the Canadians mentioned that most of the advances in modelling, especially for the finite element techniques was going on in the United States. As this was a primarily tidal meeting, there were academic ties to the United States through Professor Klaus Wyrtki of the University of Hawaii, who has actively worked in the region, particularly in Indonesia. Some of the ASEAN scientists were trained as graduate students by Professor Wyrtki. However, after talking with some of the younger scientists, it was clear that they would now do graduate or postgraduate work in Europe or Australia. Part of this is a residual of the British Commonwealth status in Singapore and Malaysia, while the rest is the recognition that in many areas such as tides, Europe is now in the forefront of science.

One thing is certain, the ASEAN nations, led by Singapore, are united in the goal of economic development and are actively and vigorously supporting advances in both science and technology.

Dr. Pat Wilde joined the staff of the Office of Naval Research Asian Office (ONRASIA) in July 1991 as a liaison scientist specializing in ocean sciences. He received his Ph.D. in geology from Harvard University in 1965. Since 1964, he has been affiliated with the University of California, Berkeley in a variety of positions and departments, including Chairman of Ocean Engineering from 1968 to 1975 and Head of the Marine Sciences Group at the Lawrence Berkeley Laboratory (1977-1982) and on the Berkeley campus (1982-1989). He joined ONRASIA after being the Humboldt Prize Winner in Residence at the Technical University of Berlin. Dr. Wilde's speciality is in paleo-oceanography and marine geochemistry, particularly in the Paleozoic and Anoxic environments. He maintains an interest in modern oceanography through his work on deep-sea fans, coastal and deep-sea sediment transport, and publication of oceanographic data sheets showing the bathymetry with attendant features off the West Coast of the United States, Hawaii, and Puerto Rico.

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